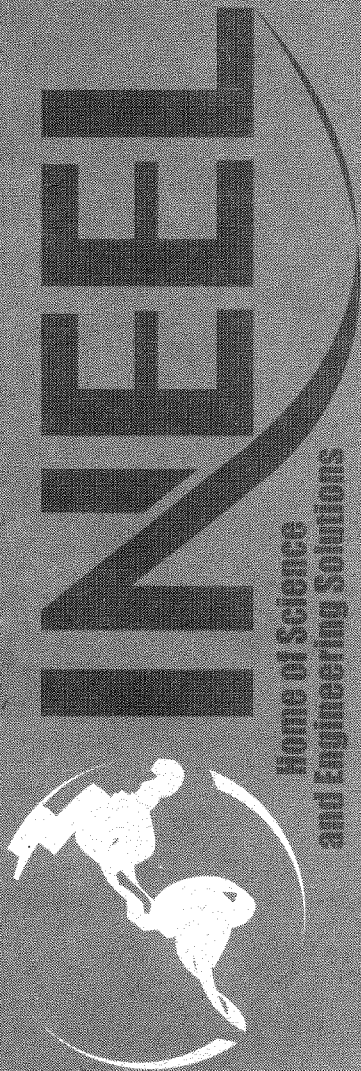


Central Facilities Area Landfills I, II, and III Annual Monitoring Report (2002)

September 2003



*Idaho National Engineering and Environmental Laboratory
Bechtel BWXT Idaho, LLC*

Central Facilities Area Landfills I, II, and III Annual Monitoring Report (2002)

September 2003

**Idaho National Engineering and Environmental Laboratory
Idaho Completion Project
Idaho Falls, Idaho 83415**

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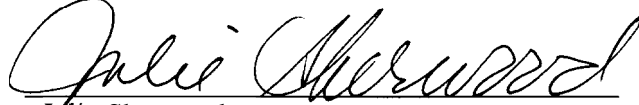
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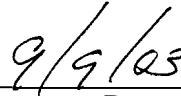
September 2003

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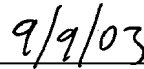


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ABSTRACT

This report summarizes the monitoring data for fiscal year 2002 for the Central Facilities Area (CFA) Landfills I, II, and III. Landfill monitoring is conducted pursuant to the requirements delineated in the *Record of Decision Declaration for Central Facilities Area Landfills I, II, and III (Operable Unit 4-12) and No Action Sites (Operable Unit 4-03)* to ensure the effectiveness of the remedy.

This annual monitoring report includes a review of the monitoring data collected in support of the remedial action. Data collection and analysis included soil gas monitoring, groundwater monitoring, and landfill moisture monitoring. The soil gas monitoring consisted of one round of samples from five locations and four depths at each location, or a total of 20 samples. The groundwater monitoring consisted of sampling 11 wells for volatile organic compounds, metals, and anions. The landfill moisture monitoring consisted of neutron-probe monitoring data from five locations and time-domain reflectometry (TDR) data from four deep profile locations.

The October 2002 water-level map constructed using the new borehole deviation corrections indicates a groundwater flow direction of southeast for Landfill II and southwest to southeast to Landfills I and III. The influence of the CFA production wells on groundwater gradients in the CFA area needs to be examined.

The groundwater data indicated that nitrate was the only analyte detected above a maximum contaminant level (MCL). Nitrate was detected above its MCL of 10 mg/L in wells CFA-MON-A-002 (19.8 mg/L-N) and CFA-MON-A003 (11 mg/L-N). Groundwater gradients indicate that the nitrate in CFA-MON-A-002 and -003 is moving away from the CFA production wells.

Iron was detected above its secondary MCL (SMCL) of 300 µg/L in five samples, and aluminum was detected above its SMCL of 200 µg/L in one sample. Given the pH of the groundwater is around 8 and has a high dissolved oxygen content, both the iron and aluminum are probably due to suspended particulates or possibly well materials in the case of iron.

The soil gas monitoring showed that most analytes were within their historical ranges. The primary soil gas contaminants, chlorinated solvents, their degradation products, and freons, do not appear to be affecting groundwater, since they were not detected in groundwater. However, the revised groundwater gradients presented in this report indicate that the groundwater monitoring system at the CFA landfills may not provide sufficient coverage to ensure that the groundwater samples being collected are representative of groundwater quality downgradient of the CFA landfills. The analytes that most frequently exceeded their historical ranges were tetrachloroethene, dichlorodifluoromethane, and trichlorofluoromethane. The compound occurring at the highest concentrations was 1,1,1-trichloroethane at GSP3-1 at Landfill III at 8,300 parts per billion by volume (ppbv). And 1,1,1-trichloroethane was detected at levels above 2,000 ppbv at GSP1-1 at Landfill I and GSP3-2 at Landfill III. Other compounds occurring above 2,000 ppbv include trichlorofluoromethane

(2,700 ppbv at GSP3-2), 1,1-dichloroethane (2,500 ppbv at GSP2-2 at Landfill 11), and dichlorodifluoromethane (2,100 ppbv at GSP3-2 at Landfill 11).

The moisture monitoring at CFA Landfill III indicated no recharge, but the moisture monitoring results at CFA Landfill II were mixed. The landfill moisture monitoring did not detect recharge in CFA Landfill III at the two TDR and neutron-probe access tube (NAT) locations. Recharge comparable to the background location occurred at NAT LF3-03 located on the edge of CFA Landfill III. The TDRs at CFA Landfill II did not detect any recharge, but NAT LF2-07 had almost 3 in. of recharge. The NAT, LF2-03, located on the edge of CFA Landfill II had less than the background amount of infiltration.

Comparing the data for NAT LF3-05 before and after the installation of the new cover shows that deep drainage or recharge was significantly reduced by the installation of the new cover. At CFA Landfill II, the decreases in recharge after the installation of the new cover are also significant at LF2-07.

The new water-level data, re-evaluated chemistry data, and modeling results suggest the CFA-08 drainfield may not be responsible for the nitrate contamination in CFA-MON-A-002 and -003. The data suggest the CFA-04 dry pond is a better candidate as the source of the nitrate contamination. However, more information is needed on the types and quantities of nitrate disposed of in the CFA-04 dry pond.

It is recommended that the nitrogen isotope samples be retaken and that the $\delta^{18}\text{O}$ of nitrate also be determined to confirm the source. The wells for the $\delta^{15}\text{N}$ nitrate and $\delta^{18}\text{O}$ nitrate resampling would include the three CFA-MON wells, CFA-1, CFA-2, LF3-08, LF2-08, and LF2-11. Because the pumping effects on groundwater gradients south of the CFA landfills is unknown, it is also recommended that the capture zones of the CFA production wells be determined to aid in the evaluation of groundwater flow paths.

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ACRONYMS

bls	below land surface
CEL	Chemical Engineering Laboratory
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFA	Central Facilities Area
EPA	Environmental Protection Agency
ESRP	Eastern Snake fiver Plain
ET	evapotranspiration
FFA/CO	Federal Facility Agreement and Consent Order
INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
MCL	maximum contaminant level
NAT	neutron-probe access tube
NOAA	National Oceanic and Atmospheric Administration
Ou	operable unit
PBF	Power Burst Facility
ppbv	parts per billion by volume
ppm	parts per million
PRG	preliminary remedition goal
ROD	record of decision
SDA	Subsurface Disposal Area
SMCL	secondary maximum contaminant level
SRPA	Ssnake fiver Plain Aquifer
STF	Security Training Facility
TDR	time domain reflectometry
TKN	total Kjeldahl nitrogen

USGS	United States Geological Survey
VOC	volatile organic compound
WAG	waste area group

Central Facilities Area Landfill I, II, and III Annual Monitoring Report (2002)

1. INTRODUCTION AND PURPOSE

Post-remedial action monitoring required by the record of decision (ROD) (DOE-ID 1995) is being carried out per the *Post Record of Decision Monitoring Work Plan Central Facilities Area Landfills I, II, and III Operable Unit 4-12* (INEL 1997a) and the *Field Sampling Plan for the Post Record of Decision Monitoring Central Facilities Area Landfills I, II, and III Operable Unit 4-12* (INEL 1997b). The results of the remedial action are summarized in the *Remedial Action Report CFA Landfills I, II, and III Native Soil Cover Project Operable Unit 4-12* (DOE-ID 1997). The location of the Central Facilities Area (CFA) landfills at the Idaho National Engineering and Environmental Laboratory (INEEL) is shown on Figure 1.

The purpose of this annual monitoring report is to present groundwater and soil gas monitoring results for 2002 and vadose zone monitoring results from October 2001 to October 2002 conducted at the CFA landfills in support of the Operable Unit (OU) 4-12 ROD. Previous monitoring results are contained in the five-year review (DOE-ID 2002a). Groundwater, infiltration, and vadose-zone monitoring were conducted to monitor the effectiveness of the remedial action. This report does not address institutional controls and land use restrictions.

1.1 Regulatory Background

The Federal Facility Agreement and Consent Order (FFA/CO) and its associated action plan (DOE-ID 1991) were negotiated and signed by the Department of Energy Idaho Operations Office, the Environmental Protection Agency (EPA), and the Idaho Department of Health and Welfare (i.e., the Agencies) in December 1991 to implement remediation of the INEEL under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The goals of the FFA/CO are to ensure (1) potential or actual INEEL releases of contaminants to the environment are thoroughly investigated in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR 300), and (2) appropriate response actions are taken to protect human health and the environment. The FFA/CO established the procedural framework and schedule for developing, prioritizing, implementing, and monitoring response actions at the INEEL in accordance with CERCLA and the Resource Conservation and Recovery Act and the Idaho Hazardous Waste Management Act. The FFA/CO is consistent with the general approach, approved by the EPA and Department of Energy, where agreements with states as full partners would allow site investigation and cleanup to proceed using a single road map to minimize conflicting requirements and maximize limited remediation resources. For management purposes, the FFA/CO divided the INEEL into 10 waste area groups (WAGs).

CFA, designated as WAG 4, incorporated 13 OUs originally containing a total of 44 individual sites. After publication of the FFA/CO, eight additional sites were formally assigned to OUs within WAG 4. In total, 52 sites are incorporated in OU 4-13 comprehensive remedial investigation/feasibility study for WAG 4 (DOE-ID 2000). OU 4-12 consisted of three landfills. The OU 4-12 ROD (DOE-ID 1995) documented that the risk associated with CFA landfills was found to be within the generally accepted limits of CERCLA or Superfund (i.e., the risk assessment indicated that the landfills do not pose an unacceptable threat to human health and the environment). As is typical for landfills, uncertainty about the waste disposal history resulted in a level of uncertainty for characterizing potential future risk, particularly as it relates to the potential for contaminant migration through leaching and cover erosion. Therefore, a remedial action of containment, consistent with EPA's presumptive remedy guidance for CERCLA municipal landfills, was warranted for the site.

The requirement for monitoring of the landfills was established in the OU 4-12 ROD (DOE-ID 1995). The remedial design specified the manner in which monitoring of groundwater, cover infiltration, and the vadose zone would be carried out (DOE-ID 1996). The post-ROD monitoring work plan was designed to provide data for use in evaluating whether the remedial action objectives stated in the ROD are being met (INEL 1997a).

1.2 Physical Characteristics of the CFA Landfills

The CFA landfills are located on the Eastern Snake River Plain (ESRP) in Big Lost River alluvial deposits overlying basalt bedrock. The sediments composing these deposits are primarily sands and gravels and contain very few fine-grained materials. However, in some places a clay-rich layer 0 to 9 ft thick exists above the bedrock (Ansley et al. 1988). Depth to basalt at these landfills ranges from 10 to 37 ft. The vadose zone, the portion of the subsurface that extends from the land surface down through the subsurface to the water table, at the CFA landfills is approximately 480 ft thick. The vadose zone is composed of a relatively thin layer of surface sediments, (where wastes were disposed) and thick sequences of interfingering basalt flows containing interbedded sediments. As a result of the relatively low annual precipitation, high potential evapotranspiration (ET), and the deep water table, the vadose zone soils at the landfills tend to be relatively dry during most of the year. The spring snowmelt provides the greatest source of water available for infiltration into the landfills. The Snake River Plain Aquifer (SRPA), one of the largest and most productive groundwater resources in the United States, underlies the CFA landfills. The SRPA is listed as a Class I aquifer, and EPA has designated it as a sole-source aquifer. The SRPA consists of a series of saturated basalt flows and interlayered pyroclastic and sedimentary materials that underlie the ESRP. The depth to water at the CFA landfills varies from about 476 ft to just over 495 ft.

1.2.1 CFA Landfill I

CFA Landfill I occupies a total surface area of approximately 8.25 acres and consists of three subunits: the rubble landfill, western waste trench, and northern waste trench. The rubble landfill originated as a gravel quarry that was operated by the U.S. Navy from 1942 to 1949. The quarry was used as a disposal area for sitewide waste disposal sometime after 1949. Wastes were discarded in the landfill from the 1950s to 1984. The surface area of the rubble landfill is estimated to be 5.5 acres, and its depth is estimated to be 12 to 15 ft. The rubble landfill is covered with approximately 1 to 5 ft of soil overlain with a layer of gravel. The surface of the western waste trench is approximately 2 acres and consists of smaller waste trenches, each excavated to a size of 8 x 10 ft deep x 50 ft long. The western waste trench is west of the present-day road separating Landfill I and Landfill III and is actually covered by the Landfill III cap. Each of the smaller trenches is separated from the other by 15 ft of undisturbed soil. Filled trenches are covered with 1 to 5 ft of soil. The northern waste trench is identified from aerial photographs and has a surface area of approximately 0.75 acres. Information pertaining to its true dimensions is limited. It is covered with soil and is not discernible at the surface.

1.2.2 CFA Landfill II

CFA Landfill II encompasses approximately 15 acres and is located in the southwest corner of an abandoned gravel pit. It received waste from September 1970 until it was closed in September 1982. Depth to basalt at this landfill varies from 15 to 37 ft, based on a seismic refraction survey and a subsurface borehole drilling investigation. However, the landfill waste profile is estimated to range in depth from 12 to 28 ft, because the pit was probably not excavated beyond the base of the gravel-bearing unit and into the clay material. Hand augering at 60 sampling sites indicated the original CFA Landfill II soil cover ranged in thickness from 0.33 to 3.17 ft, with an overall mean of 1.5 ft. The landfill surface is gently undulating due to differential settling of the waste with a stand of crested wheatgrass.

1.2.3 CFA Landfill III

CFA Landfill III consists of six trenches that cover approximately 12 acres. It opened in October 1982 after CFA Landfill II was closed and operated until December 1984. Depth to the underlying basalt is 10 to 33 ft, based on a seismic refraction survey. The landfill waste profile is estimated to be 13 ft deep on average. It was common practice to excavate the landfill trenches, leaving a soil layer intact between the wastes and underlying basalt. The original CFA Landfill III soil cover ranged in thickness from 1 to 8 ft, with an overall mean of 2.83 ft, based on augering results. Ground-penetrating radar measurements estimate the average original soil cover thickness to be 2 to 3 ft. The landfill surface is also gently undulating due to differential settling of the waste with a stand of crested wheatgrass.

1.3 Description of Remedial Action

Based upon consideration of the CERCLA requirements, the detailed analysis of alternatives, and public comments, the Agencies selected uniform containment with native soil cover, institutional controls, and monitoring as the most appropriate remedy for the CFA landfills. Containment with a native soil cover is believed to be the best alternative for minimizing public risk and providing long-term protection of the SRPA.

The major components of the remedy included (1) placement of a uniform native soil cover over Landfills I, II, and III; (2) the implementation of institutional controls; and (3) the periodic monitoring of groundwater, infiltration, and vadose zone.

The native soil cover consisted of three layers: (1) a general backfill layer that brought the existing grade up to the design slope (rough grade), (2) a compacted low-permeability soil layer, and (3) a topsoil layer that created the final grade and allows for growth of a vegetative cover. To install the cover over each landfill, the landfill was initially grubbed to remove surficial organic material in an effort to minimize void creation due to decomposition. Fill material for all three layers was obtained from Spreading Area "B" at the INEEL and placed over the landfills. The fill material was described as a lean clay with sand. The particle size analysis had 84.1% of the material passing through a No. 200 sieve (less than 0.075 mm average diameter). Both the general backfill and low-permeability soil layers were compacted to 95% of maximum dry density at 0 to +4 percentage points from optimum moisture content. The general backfill layer was emplaced with a maximum 6-in. compacted lift thickness. The low-permeability soil layer was placed in maximum 8-in. loose lifts to attain a maximum 6-in. compacted lift thickness. The final topsoil layer was emplaced with no compaction. In addition, for Landfill II, a riprap layer was installed at the extreme northeast face of the landfill, rather than revegetating the area, in an effort to prevent erosion due to the steepness of the slope. A detailed description of the remedial action, including the installation of the landfill covers, is provided in the *Remedial Action Report CFA Landfills I, II, and III Native Soil Cover Project Operable Unit 4-12* (DOE-ID 1997).

1.4 Monitoring Activities

The groundwater, soil gas, and moisture monitoring activities are summarized as follows:

- Groundwater monitoring
 - A total of 11 monitoring wells were sampled. Seven monitoring wells in the vicinity of the landfills were sampled, and four monitoring wells south of CFA were sampled.
 - Water-level measurements were taken from 31 wells in October 2002 to determine groundwater flow directions.

- Well deviation surveys were performed on 15 wells in November 2002.
- Soil gas monitoring
 - Five soil gas monitoring wells were monitored near the landfills to determine the volatile organic compounds (VOCs) in soil gas at four depths in the vadose zone at each location. The depths were near the soil/basalt interface (–10 ft), in the basalt above the first interbed (–35 ft), in the basalt below the first interbed (–70 ft), and a deep sample approximately 30 ft below the third depth (–100 ft). One round of soil gas samples was collected in 2002.
- Moisture monitoring
 - Soil moisture readings were obtained monthly from five neutron-probe access tubes (NATs) at intervals to a depth of approximately 20 ft. Three NATs are associated with CFA Landfill II, with one NAT located on the landfill, one on the edge of the landfill, and one adjacent to the landfill. On Landfill III, one NAT is located on the landfill, and one NAT is located on edge of the landfill. The moisture monitoring data cover the period from October 2001 through October 2002.
 - Time domain reflectometry (TDR) moisture data were obtained from a total of four arrays at 1-hr intervals from the surface to a depth of 8 ft. Two arrays were located at CFA Landfill II, and the other two arrays were located at CFA Landfill III. The TDR monitoring data cover the period from October 2001 to October 2002.

1.5 Report Organization

Section 2 of this report presents the groundwater monitoring results for the CFA landfills. Section 3 describes the soil gas monitoring results, and Section 4 describes moisture monitoring of CFA Landfill II and III soil covers. Section 5 presents a re-evaluation of the source of the nitrates found in two wells south of CFA. Section 6 presents a summary of the monitoring results. Section 7 presents recommendations for further action. References are provided in Section 8.

2. GROUNDWATER MONITORING RESULTS

Groundwater monitoring has been conducted in order to ensure drinking water standards are not exceeded in the SRPA due to migration of contaminants from the landfills. Groundwater samples were collected from 11 wells in the vicinity of the CFA landfills. Groundwater samples were collected and analyzed for VOCs, anions, metals, and alkalinity. In addition, groundwater-level measurements were obtained from 31 wells located in the vicinity of the CFA landfills (see Figure 2).

2.1 Water-Level Measurements

Water-level measurements were taken at 31 wells at and near CFA in October 2002 (see Table 1). The depth to groundwater was determined using surveyed measuring point elevations and well deviation correction factors. Water-level measurements were corrected to mean sea level using newly completed well deviation surveys done with the United States Geological Survey (USGS) digital gyroscope in November 2002.

A groundwater-level contour map was plotted for the October 2002 data using the new deviation correction factors (see Figure 3). The apparent groundwater flow direction from CFA Landfills III and I varies from southeast to south to southwest. The apparent direction of groundwater flow from Landfill II is predominantly southeast. The groundwater-level contour map indicates that areas of Landfills I and II are not covered by the current groundwater monitoring system. The influence of the CFA production wells on the groundwater contours south of the CFA landfills is unknown.

The groundwater gradient in the area covered by the water-level measurements varies considerably (see Figure 3). The gradient is slight over the area between the Idaho Nuclear Technology and Engineering Center (INTEC) and the CFA landfills (more than a mile), with less than 2 ft of head difference. Steeper gradients are present south of CFA and to the east of CFA between the Security Training Facility (STF) and the Power Burst Facility (PBF). From LF2-09 to CFA-MON-A-003, there is an average gradient of approximately 4 ft per mile; from LF3-10 to M12S, there is an average gradient of about 4.3 ft per mile.

2.2 Groundwater Analytical Data

Groundwater samples were collected and analyzed for VOCs, anions, metals, and alkalinity. The groundwater monitoring results are summarized for detected analytes at CFA Landfill III (see Table 2), CFA Landfill II (see Table 3), and downgradient of CFA (see Table 4). A complete listing of the groundwater results for samples collected in 2002 are provided electronically in Appendix A.

Groundwater samples were collected from 11 wells in the vicinity of the CFA landfills (see Figure 2). Groundwater samples were collected from wells downgradient from the former and current sewage treatment facilities (i.e., wells CFA-MON-A-001, CFA-MON-A-002, CFA-MON-A-003, and USGS-083), wells downgradient from CFA Landfill II (i.e., wells LF2-08, LF2-09, and LF2-11), wells located downgradient from CFA Landfills I and III (i.e., wells LF3-08, LF3-09, and LF3-10), and a well located upgradient from CFA Landfills I and III (i.e., well USGS-128).

A comparison of the maximum concentrations for detected analytes versus background and the defined regulatory level is provided in Table 5. Nitrate was the only analyte that was detected above a maximum contaminant level (MCL), and iron and aluminum were above secondary MCLs (SMCLs). Nitrate concentrations greater than the 10-mg/L MCL for sensitive populations were present in CFA-MON-A-002 (19.8 mg/L) and CFA-MON-A-003 (11 mg/L). As defined, sensitive populations include infants. All other wells had nitrate concentrations at less than 4 mg/L. The nitrate concentrations

in CFA-MON-A-002 and -003 have remained relatively steady over time (see Figures 4 and 5). The issue of nitrate in the groundwater is discussed in further detail in Section 5.

Iron concentrations exceeded the SMCL of 300 µg/L in samples from five wells. The iron concentrations in these five wells are inconsistent with the high dissolved oxygen concentrations in these same wells, suggesting that the iron is from suspended solids or well materials. The trend of iron concentrations for CFA-MON-A-001 is shown in Figure 4. The samples for iron and the other metals were not filtered.

Aluminum was above its SMCL in LF2-11 located upgradient of CFA Landfill II. The elevated aluminum concentration is probably due to suspended solids, because aluminum solubility is very low at the pH (8) found in the well.

The wells in the vicinity of the CFA landfills have elevated levels of sodium and chloride relative to background concentrations. The elevated sodium and chloride concentrations in the CFA landfill wells are due to upgradient impacts from INTEC (DOE-ID 2002b; DOE-ID 2003). The upgradient well LF2-11 has the highest sodium concentrations.

Zinc, lead, and iron concentrations are anomalous in USGS-128. This well is located upgradient of CFA Landfills I and III, and this was the first time that USGS-128 was sampled as an upgradient well. Historically, anomalous zinc, lead, and iron concentrations in the groundwater samples collected from several wells as part of the CFA groundwater monitoring and sampling program were the result of rusting carbon-steel casing and galvanized riser pipe used in the older groundwater-monitoring wells. This is a common problem identified in wells throughout the INEEL that do not have stainless-steel casing and riser pipes. Figure 4 depicts lead and zinc concentrations for well CFA-MON-A-003, demonstrating the relationship of lead and zinc concentrations in groundwater as a result of galvanic corrosion. After replacement of the galvanized riser pipe with stainless-steel riser pipe in CFA-MON-A-003 in August 2001, the lead concentration decreased below the action level (see Figure 4). The zinc, lead, and iron concentrations in USGS-128 will continue to be tracked, but they appear to be indicative of well construction and not an indicator of a groundwater problem.

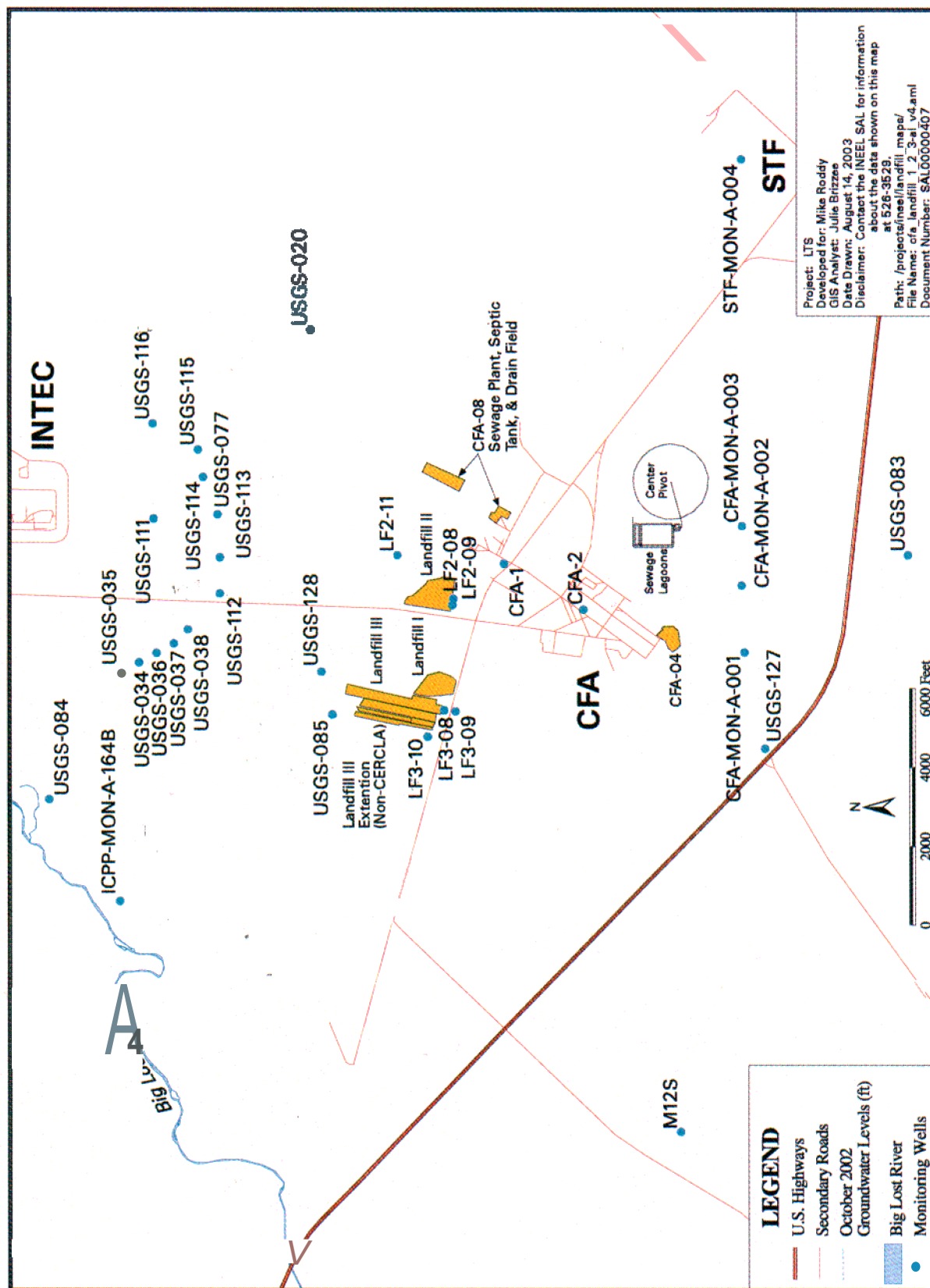


Figure 2. Locations of groundwater monitoring wells.

Table 1. Water-level measurement data for October 2002

Well	Date	Time	Depth to Water (ft bmp) ^a	Measured Stickup (ft)	Depth to Water (ft bls) ^b	Ground Elevation (ft)	Deviation Correction (ft)	Water-Level Elevation (ft)
USGS-084	10/ 1/2002	1000	487.48	1.7	485.78	4,937.90		4,453.82
USGS-085	10/ 1/2002	1036	489.72	2.27	487.45	4,939.26		4,454.08
USGS-128	10/ 1/2002	1050	484.20	1.25	482.95		0.03	
USGS-039	10/ 1/2002	1125	480.17	1.26	478.91	4,930.95		4,453.30
USGS-035	10/ 1/2002	1135	479.38	0.54	478.84	4,929.64		4,451.34
USGS-036	10/ 1/2002	1150	478.36	1.16	477.20	4,929.2		4,453.16
USGS-037	10/ 1/2002	1200	478.54	1.21	477.33	4,929.38		4,453.26
USGS-112	10/ 1/2002	1315	480.68	2.23	478.45	4,927.84	2.73	4,454.35
USGS-113	10/ 1/2002	1330	481.21	2.28	478.93	4,925.28	5.75	4,454.38
USGS-077	10/ 1/2002	1345	472.12	2.16	469.96	4,921.79		4,453.99
USGS-111	10/ 1/2002	1400	476.80	2.27	474.53	4,920.5	6.03	4,454.27
USGS-114	10/ 1/2002	1415	474.99	2.29	472.70	4,920.09	4.71	4,454.39
USGS-115	10/ 1/2002	1430	471.10	2.29	468.81	4,918.84	1.99	4,454.31
USGS-116	10/ 1/2002	1445	465.15	2.56	462.59	4,916.03		4,456.00
USGS-020	10/ 1/2002	1500	466.64	0.74	465.90	4,916.36	0.07	4,451.27
LF2-08	10/2/2002	1120		1.64	not measured			
LF2-09	10/2/2002	1145	487.25	1.44	485.81	4,932.23	5.43	4,453.29
LF2-11	10/2/2002	1246	478.50	2.01	476.49	4,928.36	0.09	4,453.97
LF3-09	10/2/2002	1315	491.72	2.4	489.32	4,941.08		4,454.16
LF3-08	10/2/2002	1325	494.82	1.61	493.21	4,940.22	5.04	4,453.66
LF3-10	10/2/2002	1350	493.05	2.12	490.93	4,942.62	0.06	4,453.87

Table 1. (continued).

Well	Date	Time	Depth to Water (ft bmp) ^a	Measured Stickup (ft)	Depth to Water (ft bls) ^b	Ground Elevation (ft)	Deviation Correction (ft)	Water-Level Elevation (ft)
ICPP-MON-A-164b	10/2/2002	1400	499.51	2.75	496.76	4,948.66		4,454.65
CFA-MON-A-001	10/2/2002	1445	492.60	2.07	490.53	4,936.44	0.04	4,448.02
CFA-MON-A-002	10/2/2002	1500	488.98	1.94	487.04	4,932.24	0.05	4,447.19
CFA-MON-A-003	10/2/2002	1515	488.32	1.61	486.71	4,930.31	0.03	4,445.24
USGS-127	10/2/2002	1535	512.02	1.85	510.17	4,956.44		4,448.12
M12S	10/2/2002	1555	538.77	1.74	537.03	4,975.23	0.07	4,440.01
USGS-083	10/2/2002	1615	503.45	2.15	501.30	4,941.59		4,442.44
PBF-MON-A-001	10/17/2002	1145	447.39	1.94	445.45	4,906.15		4,462.64
STF-MON-A-01A	10/17/2002	1215	505.59	1.77	503.82	4,941.40		4,439.35
STF-MON-A-004	10/17/2002	1230	511.27	2.22	509.05	4,945.37		4,438.54

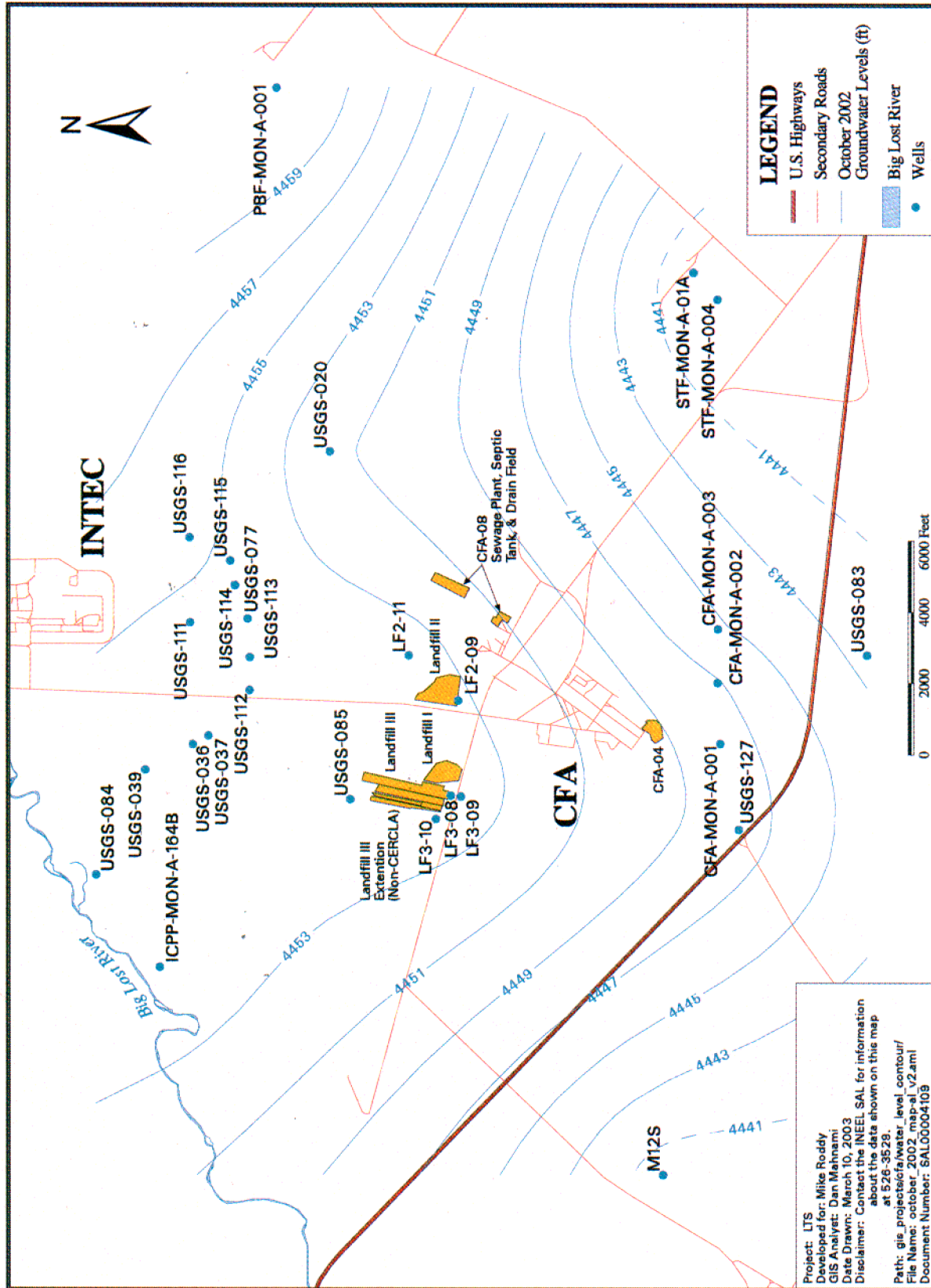


Figure 3. Groundwater level contour map for October 2002.

Table 2. Summary of detected groundwater analytes for October 2002 sampling at CFA Landfill III.^a

Compound	Sample Units	LF3-08		LF3-09		LF3-10		USGS-128		LF3-10 (Duplicate)	
<i>Znorganics</i>											
Aluminum	µg/L	75	B	190	B	—		46.2	B	—	
Arsenic	µg/L	2.6	B	—		—		2.5	B	—	
Barium	µg/L	129	B	133	B	128	B	103	B	125	B
Calcium	µg/L	60,300		70,400		60,400		55,500		60,200	
Chromium	µg/L	9.9	B	57.8		5.7	B	11.6		5.6	B
Iron	µg/L	277		377		—		1,680		—	
Lead	µg/L	—		—		—		14.5		—	
Magnesium	µg/L	17,100		20,600		15,900		14,300		15,500	
Manganese	µg/L	4.1	B	20.5		1.9	B	25.4		1.7	B
Nickel	µg/L	3.9	B	105		41.7		2.9	B	40.6	
Potassium	µg/L	4,510	B	4,420	B	3,810	B	2,990	B	3,760	B
Sodium	µg/L	37,500		37,600		35,700 E		21,900		34,900	E
Vanadmm	µg/L	3.5	B	3.6	B	2.4	B	3.5	B	2.2	B
Zinc	µg/L	49.4		291		59		726		58.9	
<i>Anions</i>											
Alkalinity	mg/L	134		132		145		148		146	
Chloride	mg/L	99.5		114		79.7		36.9		80.1	
Fluoride	mg/L	0.18	B	0.16	B	0.16	B	0.18	B	0.15	B
Nitrogen, Nitrate-Nitrite (as N) ^b	mg/L	3.12	J	3.47	J	2.8	J	1.77	J	2.74	J
Sulfate	mg/L	27.8		29.1		27.1		28.2		27.1	
<i>Organics</i>											
Toluene	µg/L	—		—		—		0.45	J	—	

a. Data qualifier flags are defined as the following: B = result is less than the contract-required reporting limit but greater than or equal to the instrument detection limit; E = post-digestion spike was outside control limits; J = the analyte was detected, but the associated values are an estimate and may be inaccurate or imprecise.

b. The nitrate data were flagged J, because the calibration range check (114%) was outside the acceptance criteria of 95 to 105%.

Table 3. Summary of detected groundwater analytes for October 2002 sampling at CFA Landfill II.^a

Compound	Sample Units	LF2-08		LF2-09		LF2-11	
<i>Znorganics</i>							
Aluminum	µg/L	43.4	B	—		240	
Arsenic	µg/L	3	B	3.7	B	—	
Barium	µg/L	154	B	184	B	160	B
Calcium	µg/L	66,500		75,900		60,400	
Chromium	µg/L	13.9		9	B	23.3	
Iron	µg/L	672		—		872	
Magnesium	µg/L	17,900		18,800		17,000	
Manganese	µg/L	5.9	B	—		8.1	B
Nickel	µg/L	4	B	—		11.7	B
Potassium	µg/L	4,540	B	5,040		4,360	B
Sodium	µg/L	41,800		43,000		44,900	
Vanadmm	µg/L	3.4	B	3.4	B	2.8	B
<i>Anions</i>							
Alkalinity	mg/L	129		126		136	
Chloride	mg/L	113		103		107	
Fluoride	mg/L	0.16	B	0.16	B	0.15	B
Nitrogen, Nitrate-Nitrite (as N) ^b	mg/L	3.37	J	3.27	J	3.3	J
Sulfate	mg/L	31.8		28.9		29.6	
<i>Organics</i>							
Toluene	µg/L	32		—		—	

a. Data qualifier flags are defined as the following: B = result is less than the contract-required reporting limit but greater than or equal to the instrument detection limit; J = the analyte was detected, but the associated values are an estimate and may be inaccurate or imprecise.

b. The nitrate data were flagged J, because the calibration range check (114%) was outside the acceptance criteria of 95 to 105%.

Table 4. Summary of detected groundwater analytes for 2002 sampling of wells downgradient of CFA.^a

Compound	Sample Units	CFA-MON-001		CFA-MON-002		CFA-MON-003		USGS-083	
<i>Znorganics</i>									
Aluminum	µg/L	107	B	165	B	65	B	3.3	B
Arsenic	µg/L	2.5	B	3	B	—		—	
Barium	µg/L	26.8	B	55.6	B	46.9	B	31	B
Calcium	µg/L	34,800		61,300		48,500		29,100	
Chromium	µg/L	10.1		20.6		12.9		13.9	
Iron	µg/L	—		440		—		—	
Lead	µg/L	—		—		—		—	
Magnesium	µg/L	13,600		25,400		21,900		11,400	
Manganese	µg/L	4.6	B	17.2		2	B	—	
Nickel	µg/L	—		42.8		—		—	
Potassium	µg/L	2,620	B	4,270	B	3,310	B	2,460	B
Sodium	µg/L	9,680		16,000		12,200		10,300	
Vanadmm	µg/L	6.6	B	5.6	B	6.2	B	8.8	B
Zinc	µg/L	24.2		91.2		35.8		175	
<i>Anions</i>									
Alkalinity	mg/L	105		108		101		99	B
Chloride	mg/L	21.6		54.4		43.2		10.2	
Fluoride	mg/L	0.18	B	0.15	B	0.19	B	0.2	B
Nitrate-Nitrite (as N) ^b	mg/L	1.62	J	19.8	J	11	J	0.71	J
Sulfate	mg/L	18.8		26.6		23.1		19.7	
<i>Organics</i>									
Methane	µg/L	230	J	130	J	—		—	

a. Data qualifier flags are defined as the following: B = Result is less than the contract-required reporting limit but greater than or equal to the instrument detection limit; J = The analyte was detected, but the associated values are an estimate and may be inaccurate or imprecise.

b. The nitrate data were flagged J because the calibration range check (114%) was outside the acceptance criteria of 95 to 105%.

Table 5. Background and regulatory levels for detected analytes

Compound	Units	Maximum Detected Value	Location of Maximum Detected Value	MCL or SMCL"	LF2-11 Upgradient Well	Background ^b	Detections Above Background and Upgradient Well	Number of Wells with Detections Above MCL or SMCL
Anions								
Alkalinity-bicarbonate	mg/L	148	USGS-128	None	136	169–174	No	NA
Chloride	mg/L	114	LF3-09	250	107	16–27	Yes	0
Fluoride	mg/L	0.2	USGS-083	2	0.15	0.3–0.5	No	0
Nitrate/nitrite	mg-N/L	19.8	CFA-MON-A-002	10	3.3	1 to 2	Yes	2
Sulfate	mg/L	31.8	LF2-08	250	29.6	24–31	Yes	0
Common Cations								
Calcium	µg/L	75,900	LF2-09	None	60,400	43,000–46,000	Yes	NA
Magnesium	µg/L	25,400	CFA-MON-A-002	None	17,000	15,000	Yes	NA
Potassium	µg/L	5,040	LF2-09	None	4,360	3,100–3,500	Yes	NA
Sodium	µg/L	44,900	LF2-11	None	44,900	14,000–17,000	No	NA
Organic Analytes								
Toluene	µg/L	32	LF2-08	1,000	ND	NA	NA	0
Methane	µg/L	230	CFA-MON-A-001	None	ND	NA	NA	NA
Inorganic Analytes								
Aluminum	µg/L	240	LF2-11	50 to 200	240	10–13	No	1
Arsenic	µg/L	3.7	LF2-09	50/10°	ND	2 to 3	Yes	0
Barium	µg/L	184	LF2-09	2,000	160	50 to 70	Yes	0
Beryllium	µg/L	ND		4	ND	N	No	0
Cadmium	µg/L	ND		5	ND	<1	No	0
Chromium	µg/L	57.8	LF3-09	100	23.3	2 to 3	Yes	0

Table 5. (continued).

Compound	Units	Maximum Detected Value	Location of Maximum Detected Value	MCL or SMCL"	LF2-11 Upgradient Well	Background ^b	Detections Above Background and Upgradient Well	Number of Wells with Detections Above MCL or SMCL
Copper	µg/L	ND		<i>1,300/1,000</i>	ND	<1	Yes	0
Iron	µg/L	1,680	USGS-128	300	872	<i>16–25</i>	Yes	5
Lead	µg/L	14.5	USGS-128	15 ^c	ND	1 to 5	Yes	0
Manganese	µg/L	25.4	USGS-128	<i>50</i>	8.1	7	Yes	0
Mercury	µg/L	ND		2	ND	N	N	0
Nickel	µg/L	105	LF3-09	None	11.7	N	N	NA
Selenium	µg/L	ND		50	ND	<1	No	0
Vanadmm	µg/L	8.8	USGS-083	None	ND	N	N	NA
Zinc	µg/L	726	USGS-128	<i>5,000</i>	ND	<i>10.5–54</i>	Yes	0

a. Numbers in italics are for SMCL.

b. Background is from two sources. Plain numbers are from Knobel, Orr, and Cecil (1992). Italicized numbers are from USGS (1999)—median and mean values.

c. The action level for lead is 15 µg/L. The proposed new MCL for arsenic is 10 µg/L.

NA = not applicable.

ND = not detected.

N = not determined.

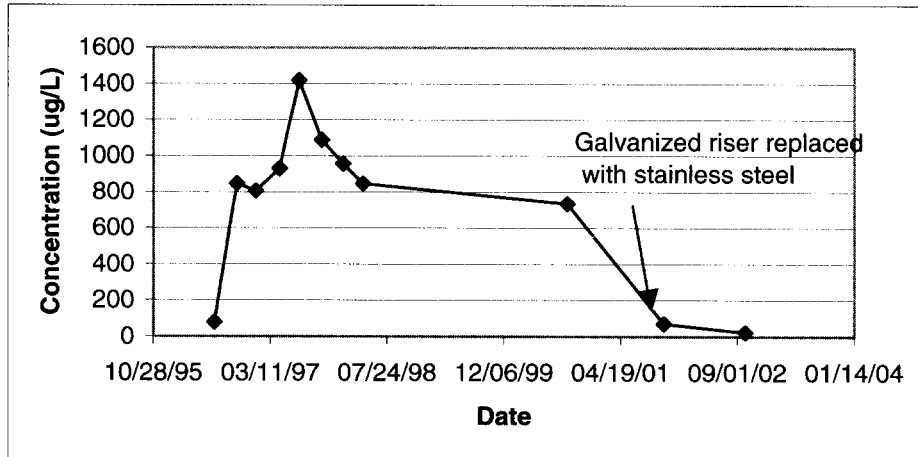


Figure 4a. Zinc in groundwater from CFA-MON-A-003.

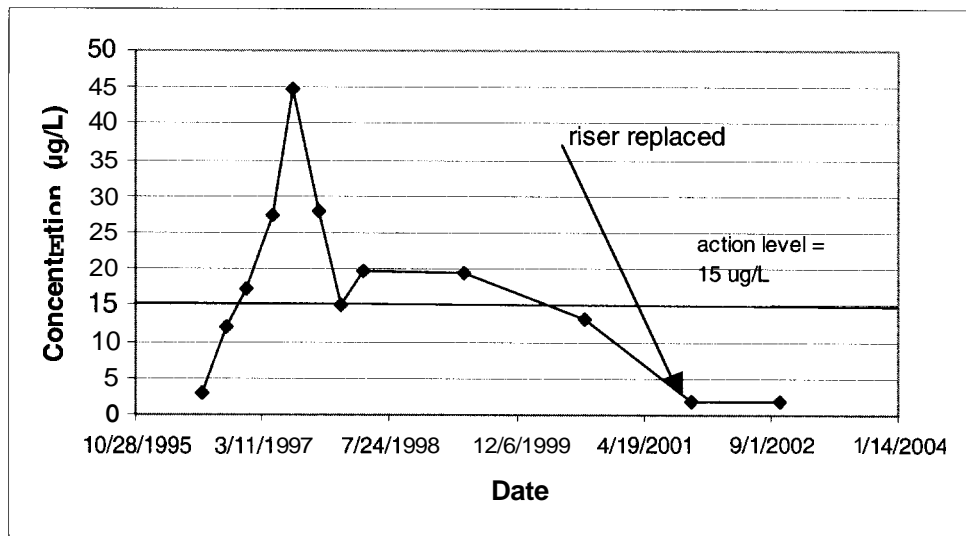


Figure 4b. Lead in groundwater from CFA-MON-A-003.

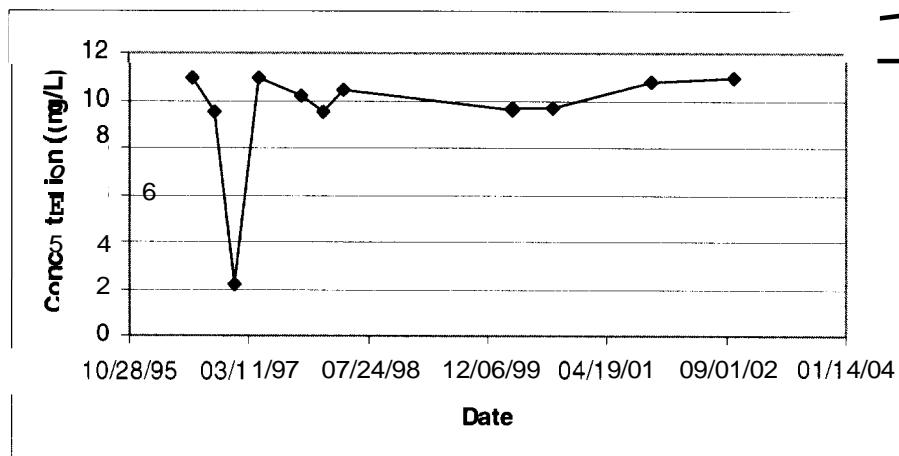


Figure 4c. Nitrate in groundwater from CFA-MON-A-003.

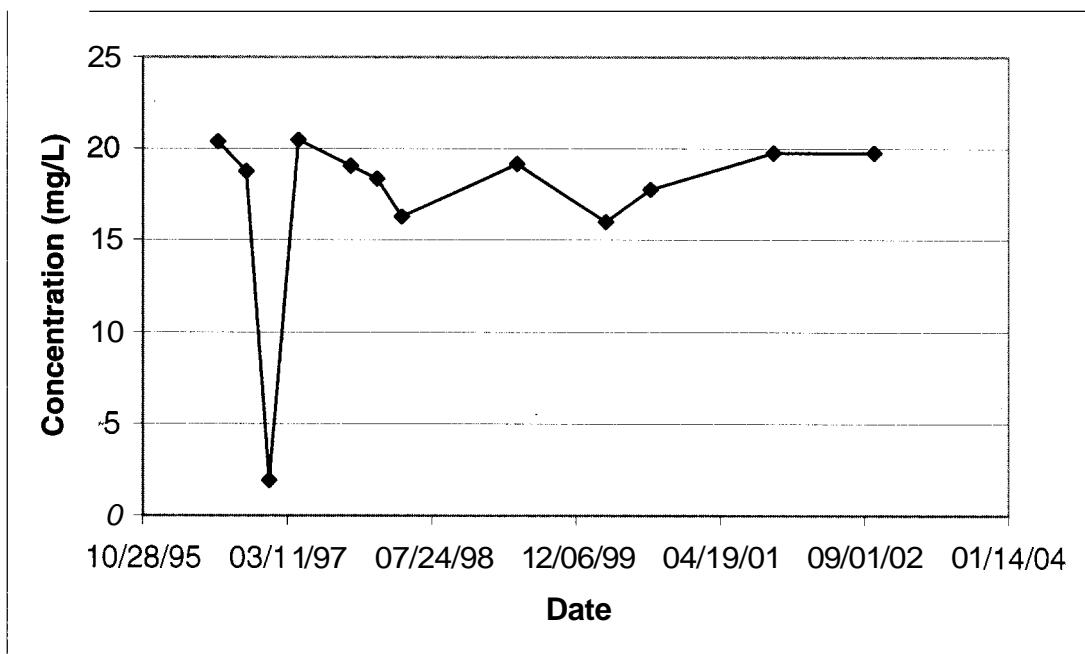


Figure 5a. Trends for nitrate in groundwater from CFA-MON-A-002.

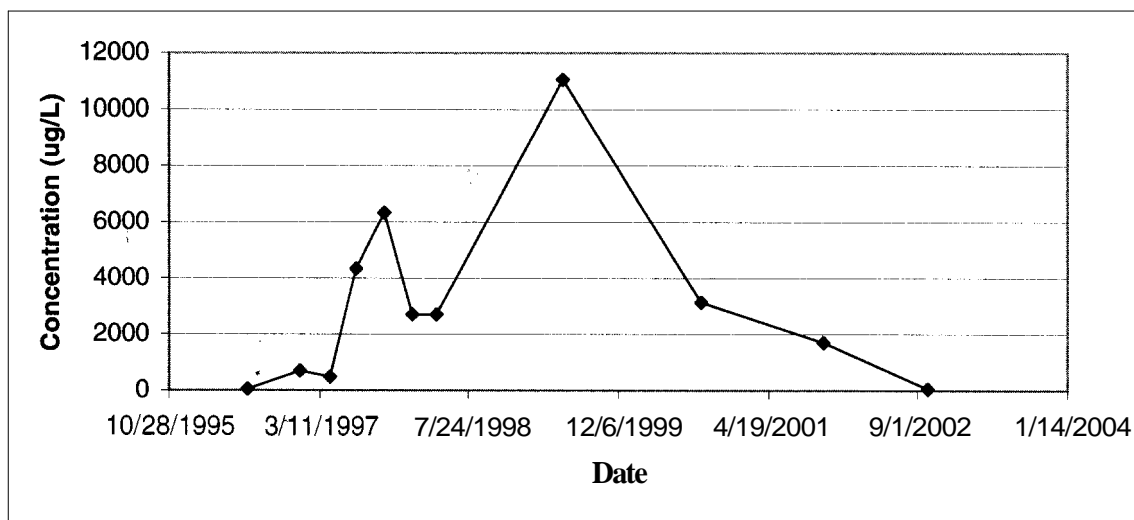


Figure 5b. Trends for iron in groundwater from CFA-MON-A-001 .

3. SOIL GAS MONITORING RESULTS

The locations of the five soil gas boreholes are shown in Figure 6. Four gas-sampling ports at each location are designed to sample soil gases from discrete depths. One shallow sampling port was placed within the surficial sediments at a depth of approximately 13 ft. A second sampling port was placed in basalt at a depth of approximately 38 ft above the shallow interbed, which is located approximately 40 to 60 ft below land surface (bls). Two deep sampling ports were placed below the shallow interbed, with perforated sections vertically separated by approximately 30 ft. The depths of these two ports are approximately 78 and 108 ft. The actual sampling depths for the gas-sampling ports are given as a footnote in Table 6. The perforated sections of the deep sampling ports were located adjacent to fracture zones in the basalt to place the sampling locations adjacent to the most probable avenue of soil gas migration. Soil gas samples were collected and analyzed for VOCs, including methane, in late May and early June 2002. The soil gas data from 2002 are compared to historical data. A summary of analytes detected in the soil gas samples is provided in Table 6, and a complete listing of results is provided electronically in Appendix A. The VOC that occurred at the highest concentration in 2002 sampling was 1,1,1-trichloroethane at 8,300 parts per billion by volume (ppbv) in GSP3-1 at a nominal depth of 77.5 ft.

Historically, VOCs that have been detected consistently in the soil gas samples include 1,1,1-trichloroethane, 1,1-dichloroethane, 1,1-dichloroethene, dichlorodifluoromethane, trichlorofluoromethane, trichloroethene, chloroethane, F-113, F-114, cis-1,2-dichloroethene, carbon tetrachloride, and tetrachloroethene. These compounds are refrigerants, common solvents, constituents found in solvents used for cleaning mechanical equipment, or degradation products of solvents. Generally, the upper soil gas locations at a depth of 10 to 13 ft bls are low in VOC concentrations, with the highest VOC concentrations at the intermediate sample port depths of approximately 35 to 38 ft bls and 70 to 78 ft bls. The VOC concentrations then generally decrease in samples collected from the lowermost locations at 100 to 108 ft bls.

Methane, which is a common by-product of anaerobic degradation of landfill wastes, was only positively identified in GSP2-2 at a depth of 107.5 ft in samples from 2002. The other samples from 2002 were flagged as non-detect because of methane in the laboratory blanks.

At GSP 1-1, most analytes are within their historical average concentration range. The analytes occurring at the highest concentrations in GSP 1-1 were 1,1,1-trichloroethane, 1,1-dichloroethene, trichloroethene, and trichlorofluoromethane. The concentration trends for these four compounds are shown in Figure 7. Tetrachloroethene was modestly higher than the previous concentrations in the 12.5- and 37.5-ft samples. Dichlorodifluoromethane was slightly above its historical range but was within historical ranges for the other sampling depths. 1,1-dichloroethene shows a slight trend toward increasing in concentration, but the last sample declined from the previous sample.

Most analytes are within historical ranges for GSP2-1. Analytes exceeding their historical ranges and greater than 100 ppbv in concentration include tetrachloroethene (37.5 and 107.5 ft), trichlorofluoromethane (107.5 ft), dichlorofluoromethane (37.5 and 107.5 ft), and F-113 (77.5 ft). None of the compounds above their historical ranges exceeded 1,000 ppbv in concentration. The VOC concentrations in GSP2-1 are generally lower than in the other gas-monitoring wells and were not plotted for that reason.

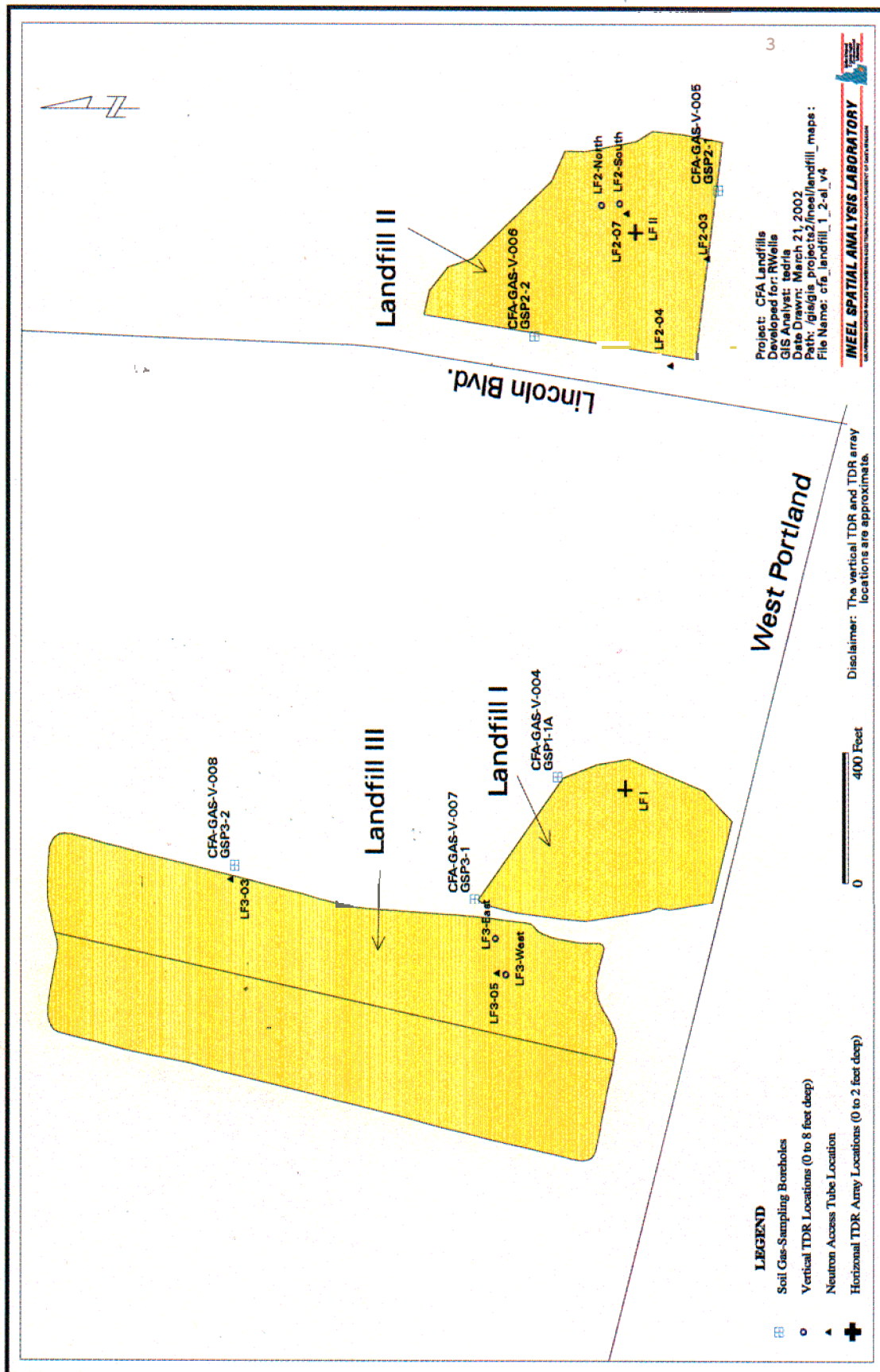


Figure 6. Locations of soil gas boreholes, TDR arrays, and NATs.

Table 6. Summary of detected soil gas analytes in ppbv for 2002.^a

Depth (ft)	Compound	GSP1-1 ^b	GSP2-1 ^c	GSP2-2 ^d	GSP3-1 ^e	GSP3-2 ^f
12.5	1,1,1-Trichloroethane	740	14 J	1,300	890	270
37.5	1,1,1-Trichloroethane	2,500	49	1,000	2,300	790
77.5	,1,1-Trichloroethane	6,000	180	770	8,300	2,400
107.5	,1,1-Trichloroethane	1,200	150	850	750	180
12.5	,1,2-TC-1,2,2-TFA (F113)	180	19	170	280	180
37.5	,1,2-TC-1,2,2-TFA (F113)	580	70	330	1,000	620
77.5	,1,2-TC-1,2,2-TFA (F113)	560	150	320	970	1,500
107.5	1,1,2-TC-1,2,2-TFA (F113)	79	120	340	69	330
12.5	1,1-Dichloroethane	130	ND	1,700	130	62
37.5	1,1-Dichloroethane	430	ND	2,500	850	280
77.5	1,1-Dichloroethane	250	78	1,200	340	450
107.5	1,1-Dichloroethane	8 J	89	1,100	10 J N D	
12.5	1,1-Dichloroethene	280	ND	99	330	17 J
37.5	1,1-Dichloroethene	1,100	ND	110	1,100	16
77.5	1,1-Dichloroethene	3,200	ND	73	4,600	440
107.5	1,1-Dichloroethene	790	ND	84	440	67
12.5	Carbon tetrachloride	ND	38	28	16	14 J
37.5	Carbon tetrachloride	ND	72	21	14 J	10 J
77.5	Carbon tetrachloride	ND	75	44	26	ND
107.5	Carbon tetrachloride	ND	51	47	ND	11 J
12.5	Chloroform	ND	ND	27	ND	ND
37.5	Chloroform	21	ND	35	37	10 J
77.5	Chloroform	26	24	18	44	11 J
107.5	Chloroform	ND	28	18	ND	ND
12.5	cis-1,2-Dichloroethene	10 J	ND	1,500	ND	16
37.5	cis-1,2-Dichloroethene	27	ND	1,200	47	55
77.5	cis-1,2-Dichloroethene	ND	ND	360	ND	160
107.5	cis-1,2-Dichloroethene	ND	ND	230	ND	ND
12.5	Dichlorodifluoromethane	190	220	1,500	270	160
37.5	Dichlorodifluoromethane	680	710	1,500	ND	690 J
77.5	Dichlorodifluoromethane	660	1000	1,200	1,100	2,100
107.5	Dichlorodifluoromethane	110	780	1,300	79	410
12.5	Tetrachloroethene	91	49	250	20	72
37.5	Tetrachloroethene	270	180	770	450	230
77.5	Tetrachloroethene	65	240	400	38	22
107.5	Tetrachloroethene	ND	170	390	9 J N D	

Table 6. (continued).

Depth (ft)	Compound	GSP1-1 ^b	GSP2-1 ^c	GSP2-2 ^d	GSP3-1 ^e	GSP3-2 ^f
12.5	Trichloroethene	130	48	200	40	83
37.5	Trichloroethene	450	73	440	450	210
77.5	Trichloroethene	1,500	48	190	160	150 J
107.5	Trichloroethene	210	66	210	16 J	9
12.5	Trichlorofluoromethane	230	37	380	310	190
37.5	Trichlorofluoromethane	800	130	860	1,300	920 J
77.5	Trichlorofluoromethane	1,100	290	2,000	1,700	2,700
107.5	Trichlorofluoromethane	150	220	2,000	120	470

a. Data qualifier flag J is defined as the analyte was detected, but its associated values are an estimate and may be inaccurate or imprecise.

b. Depths shown are proposed depths from the work plan. Actual sample depths are 8.5–11.5 ft, 43–46 ft, 64–67 ft, and 95–98 ft. Additional compounds detected and their concentrations in ppbv include acetone 120 at 77.5 ft and 28 at 107.5 ft, methylene chloride at 10J at 12.5 ft and 9J at 77.5 ft, and 2-butanone at 9J at 77.5 ft.

c. Depths shown are proposed depths from the work plan. Actual sample depths are 11–14 ft, 41–46 ft, 66–69 ft, and 94–97 ft. Additional compounds detected and their concentrations in ppbv include acetone at 16J at 107.5 ft, methylene chloride at 11J at 37.5 ft, and 1,2DC-1,1,2,2-TFA (F-114) at 24 at 77.5 ft.

d. Depths shown are proposed depths from the work plan. Actual sample depths are 15–18 ft, 39–42 ft, 64–67 ft, and 90–99 ft. Additional compounds detected and their concentrations in ppbv include acetone at 13J at 37.5 ft, methylene chloride at 35 at 37.5 ft, 1,2-dichlorobenzene at 19 at 37.5 ft, 1,2-dichloropropane at 62 at 37.5 ft, trans-1,2-dichloroethene at 10J at 12.5 ft, chlorobenzene-31 at 37.5 ft, benzene at 13J at 37.5 ft, chloroethane at 33 at 12.5 ft and 67 at 37.5 ft, and methane at 6 parts per million.

e. Depths shown are proposed depths from the work plan. Actual sample depths are 11–14 ft, 40–43 ft, 74–77 ft, and 101–104 ft. Additional compounds detected and their concentrations in ppbv include acetone at 13J at 12.5 ft; methylene chloride at 16 at 12.5 ft, 26 at 37.5 ft, 44 at 77.5 ft, and 8J at 107.5 ft; and 1,2-dichloro-1,1,2,2-tetrafluoroethane (F-114) at 46 at 77.5 ft.

f. Depths shown are proposed depths from the work plan. Actual sample depths are 9–12 ft, 44–47 ft, 68–71 ft, and 101–104 ft. Additional compounds detected and their concentrations in ppbv include acetone at 9 at 37.5 ft and 14 at 77.5 ft, and 1,2-dichloro-1,1,2,2-tetrafluoroethane (F-114) at 230 at 77.5 ft and 30 at 107.5 ft.

ND = not detected.

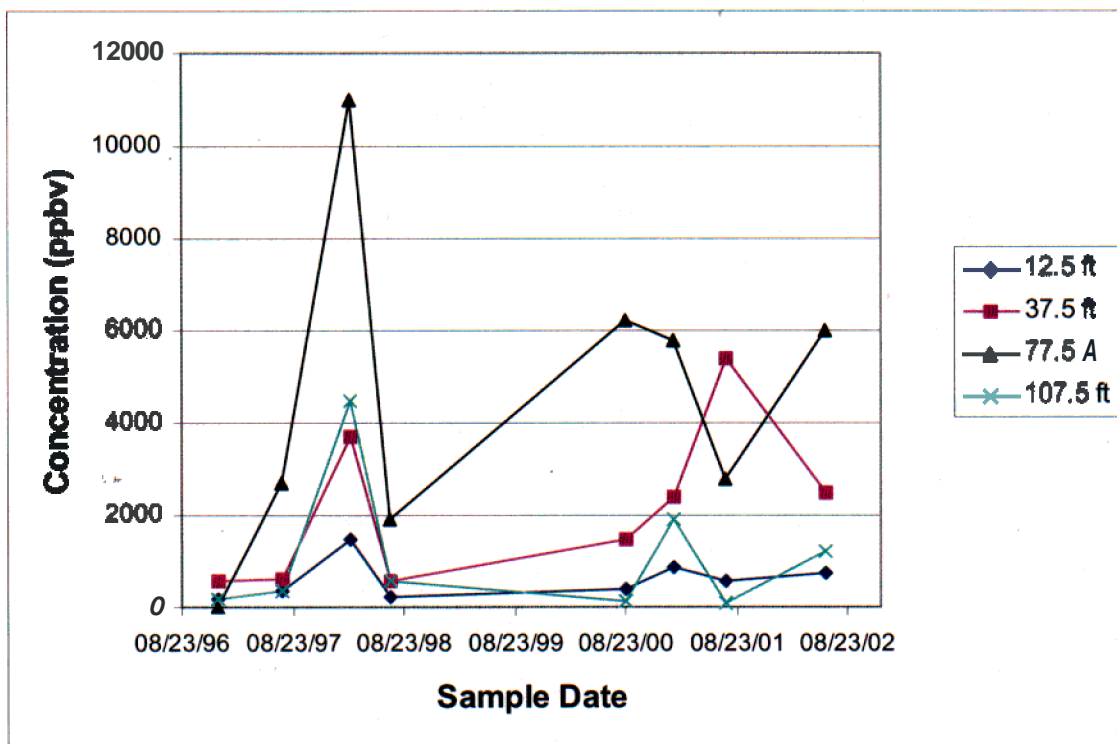


Figure 7a. 1,1,1-trichloroethane trends for GSP1-1 (CFA-GAS-V-004) at Landfill I.

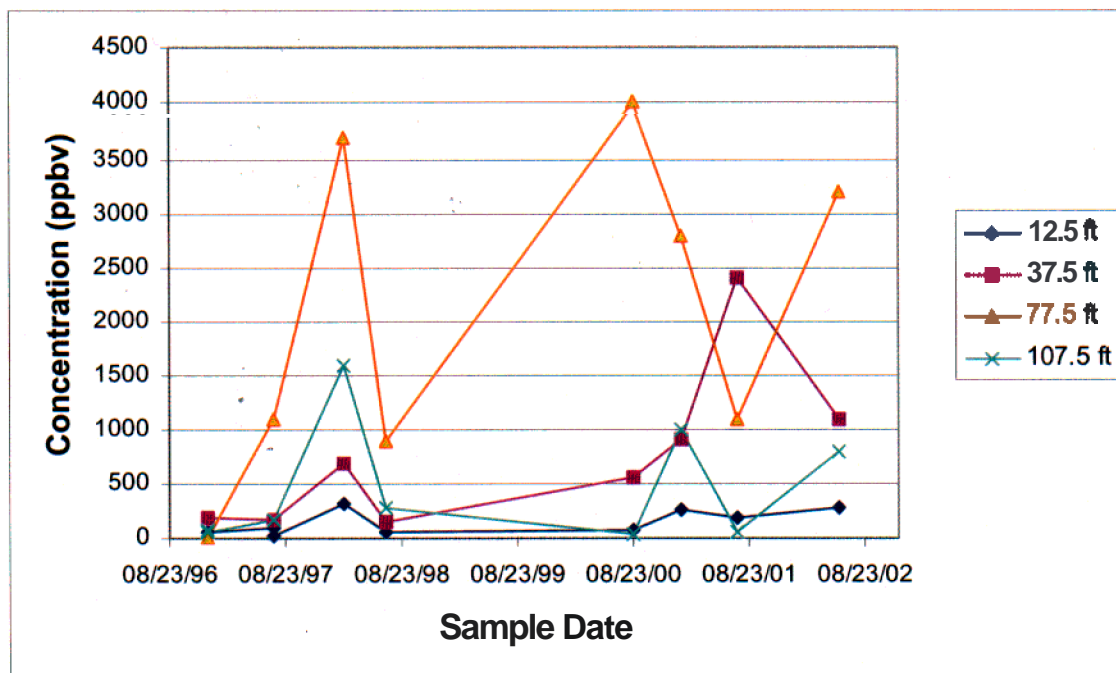


Figure 7b. 1,1-dichloroethene trends for GSP1-1 (CFA-GAS-V-004) at Landfill I.

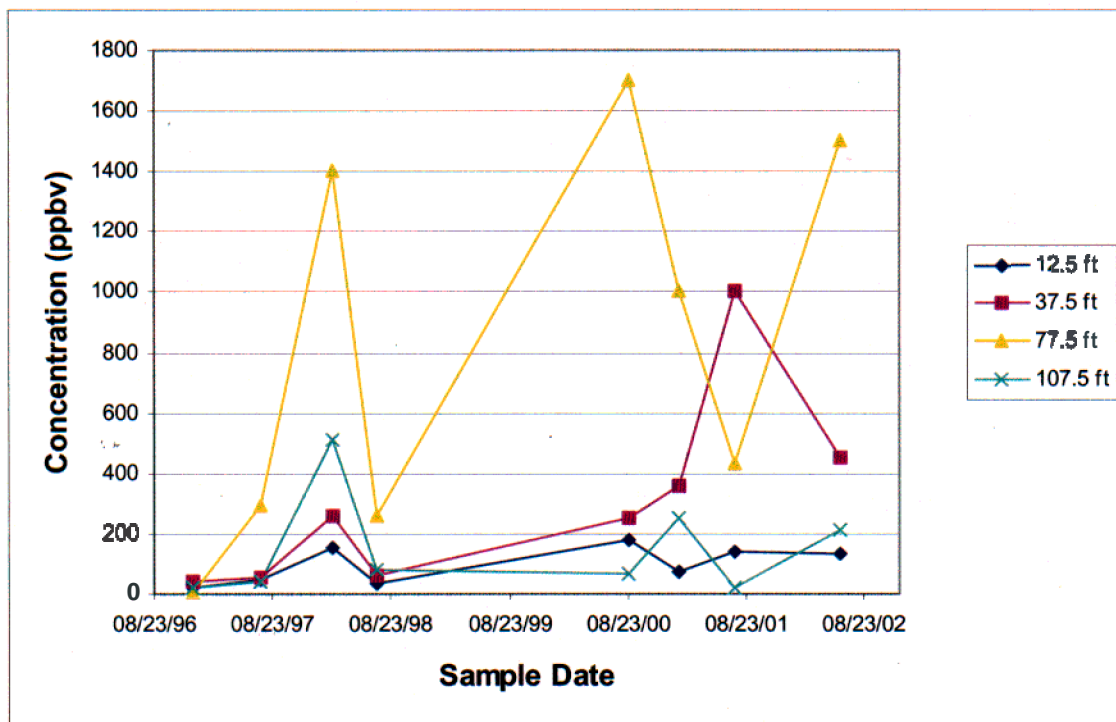


Figure 7c. Trichloroethene trends for GSP1-1 (CFA-GAS-V-004) at Landfill I.

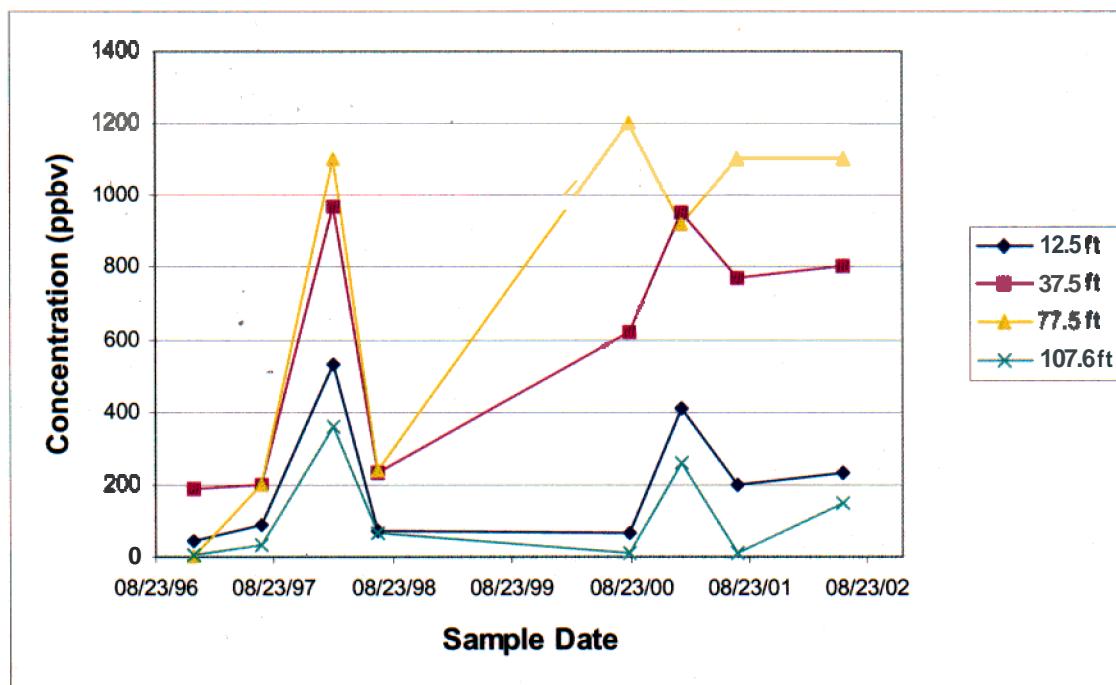


Figure 7d. Trichlorofluoromethane trends for GSP1-1 (CFA-GAS-V-004) at Landfill I.

At GSP2-2, most analytes were within their historical ranges. The compounds occurring at the highest concentrations are 1,1,1-trichloroethane, 1,1-dichloroethane, dichlorodifluoromethane, trichlorofluoromethane, and cis-1,2-dichloroethene. The concentration trends for 1,1,1-trichloroethane, 1,1-dichloroethane, dichlorodifluoromethane, and trichlorofluoromethane are shown in Figure 8 to illustrate representative data trends. Analytes exceeding their historical ranges and occurring at concentrations greater than 100 ppbv include tetrachloroethene (37.5, 77.5, and 107.5 ft), trichlorofluoromethane (77.5 and 107.5 ft), dichlorodifluoromethane (all depths), and 1,1,1-trichloroethane (77.5 ft). Trichlorofluoromethane exhibits a trend of increasing concentrations at 77.5 and 107.5 ft.

Most analytes are within historical ranges for GSP3-1. The compounds occurring at the highest concentrations are 1,1,1-trichloroethane, dichlorodifluoromethane, trichlorofluoromethane, and cis-1,2-dichloroethene. The concentration trends for 1,1,1-trichloroethane and cis-1,2-dichloroethene are shown in Figure 9 to illustrate representative data trends. Analytes detected at concentrations greater than 100 ppbv and exceeding their respective historical ranges are tetrachloroethene (37.5 ft), 1,1-dichloroethane (37.5 and 77.5 ft), dichlorodifluoromethane (77.5 ft), and trichlorofluoromethane (77.5 ft).

Most analytes are within historical data ranges for GSP3-2. The compounds occurring at the highest concentrations are 1,1,1-trichloroethane, trichlorofluoromethane, and dichlorodifluoromethane. Figure 10 is provided to show the concentration trends for 1,1,1-trichloroethane and trichlorofluoromethane, since they occur at high concentrations and show modest trends toward increasing concentrations at a depth of 77.5 ft. However, 1,1,1-trichloroethane and trichlorofluoromethane 2002 concentrations are within historical limits. Tetrachloroethene (37.5 ft), trichloroethene (77.5 ft), and cis-1,2-dichloroethene (77.5 ft) were above historical averages in 2002, but the concentrations are well below 1000 ppbv or 1 part per million (ppm).

The potential impacts of VOCs in soil gas at the CFA landfills can be evaluated by comparing deep soil gas concentrations at the CFA landfills to the preliminary remediation goals (PRGs) calculated for the Subsurface Disposal Area (SDA), an INEEL site with similar geology and hydrologic conditions. The PRGs are the estimated maximum soil gas concentrations that will not cause groundwater concentrations to exceed MCLs. The PRG range for carbon tetrachloride at the SDA is 30 to 200 ppmv at 100 to 200 ft bls (DOE-ID 1994a). The MCL for carbon tetrachloride is 5 ppb, the same as trichloroethene and tetrachloroethene. The MCL for 1,1,1-trichloroethane is 200 ppb. Given the similar geology and hydrologic conditions at the sites, and the similar nature of the contaminants (chlorinated solvents) it is reasonable to assume that the PRG calculated for the SDA can be applied at the CFA landfills to make rough approximations.

The maximum PCE and TCE concentrations measured in 2002 in the soil gas in the GSP wells at the CFA landfills are 0.77 and 1.5 ppmv, respectively. These concentrations are much lower than the PRG range calculated for carbon tetrachloride at the SDA for a similar depth. The maximum 1,1,1-trichloroethane concentration measured in the GSP wells is 8.3 ppmv. Although this value is closer to the PRG range calculated for the SDA, it is important to note that the MCL for 1,1,1-trichloroethane is 40 times higher than the MCL for tetrachloroethene, trichloroethene, and carbon tetrachloride. Given these comparisons, it is highly unlikely that the contamination in the vicinity of the GSP wells could adversely impact the aquifer.

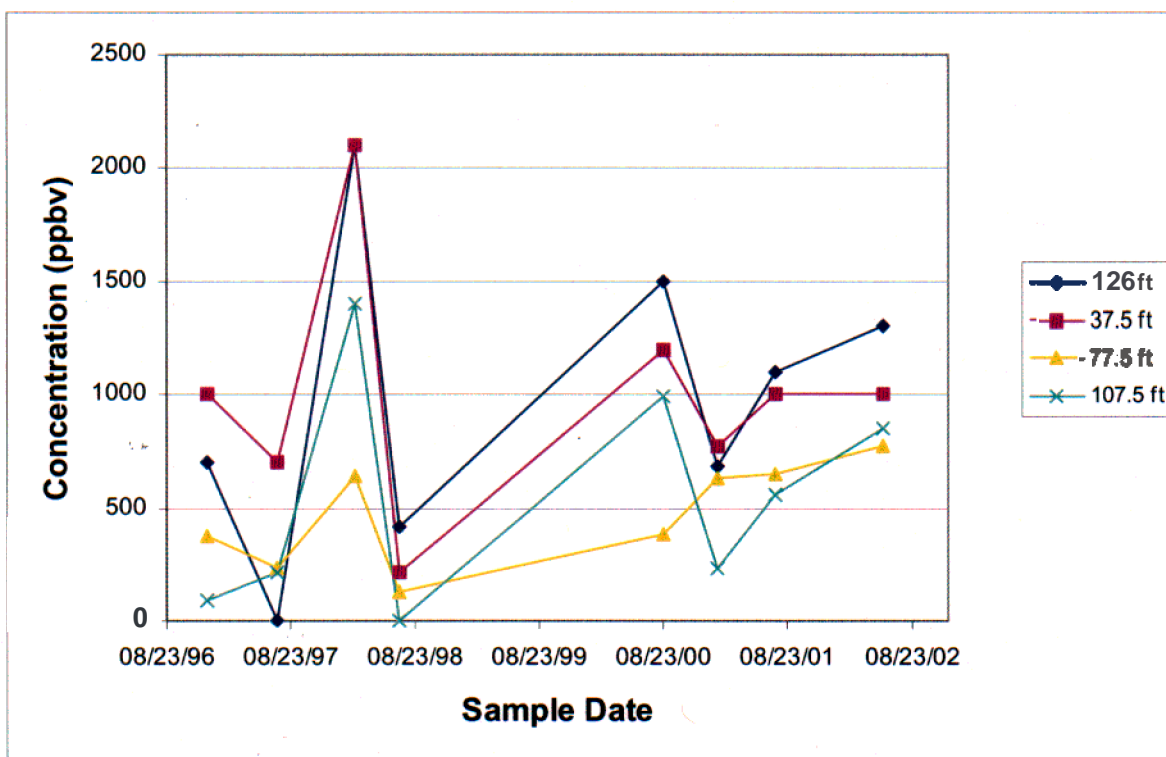


Figure 8a. 1,1,1-trichloroethane trends at GSP2-2 on Landfill II (CFA-GAS-V-006).

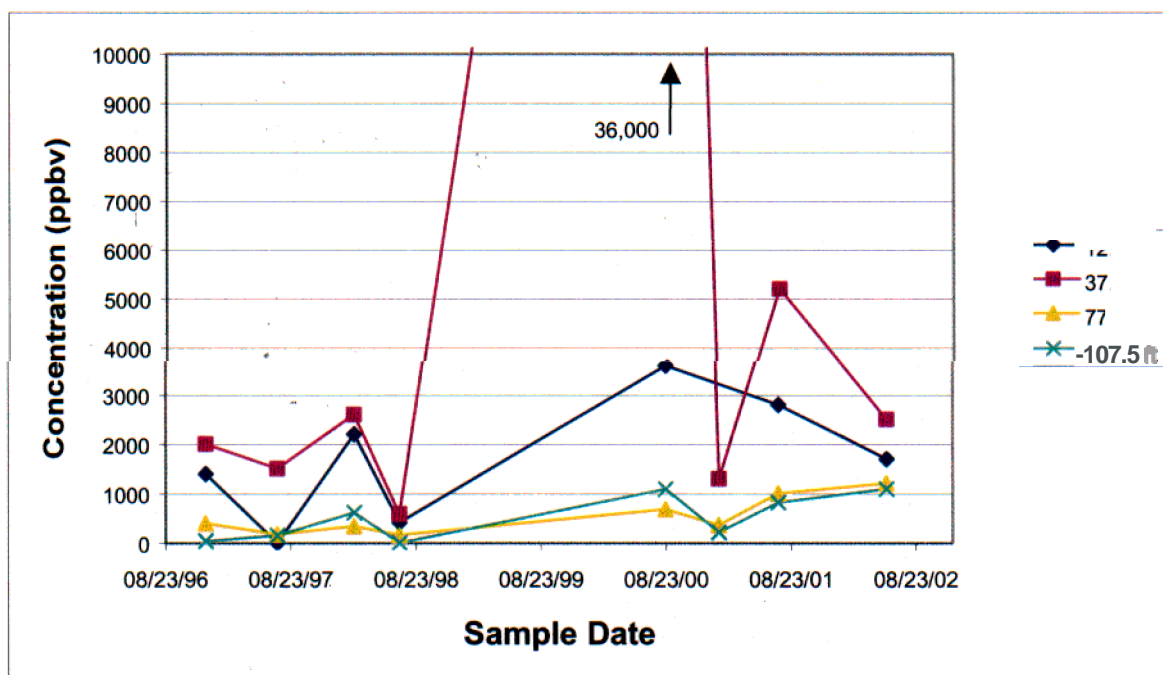


Figure 8b. 1,1-dichloroethane trends at GSP2-2 on Landfill II (CFA-GAS-V-006).

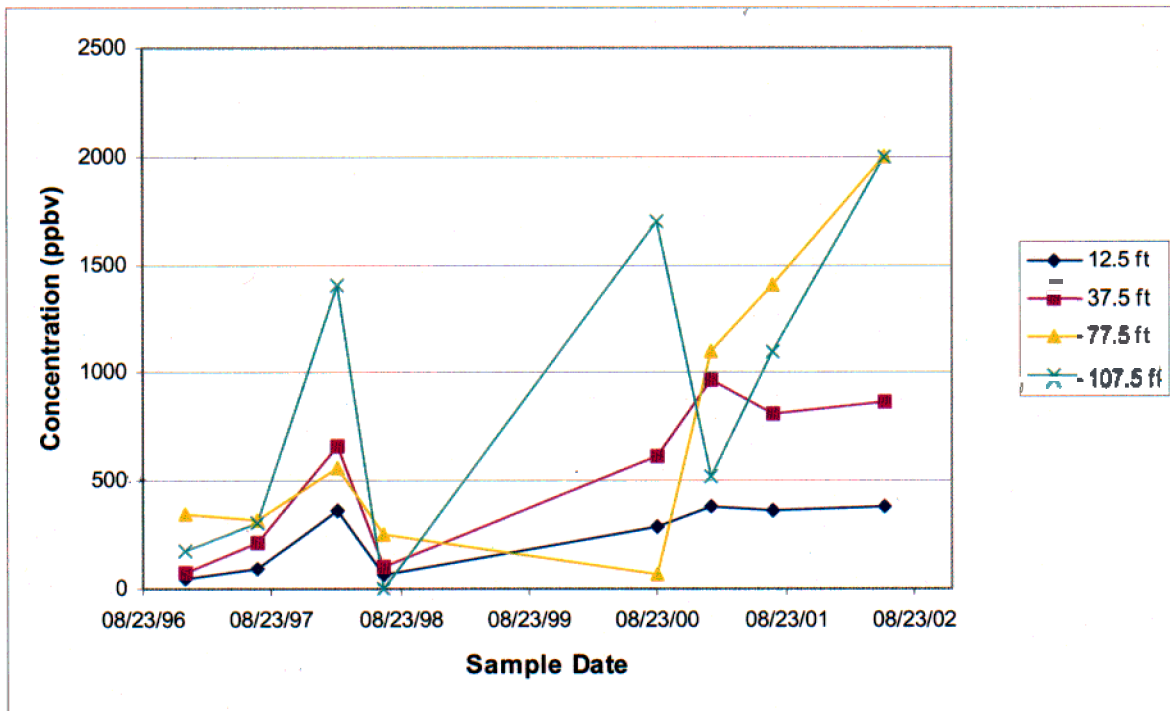


Figure 8c. Trichlorofluoromethane trends at GSP2-2 on Landfill II (CFA-GAS-V-006).

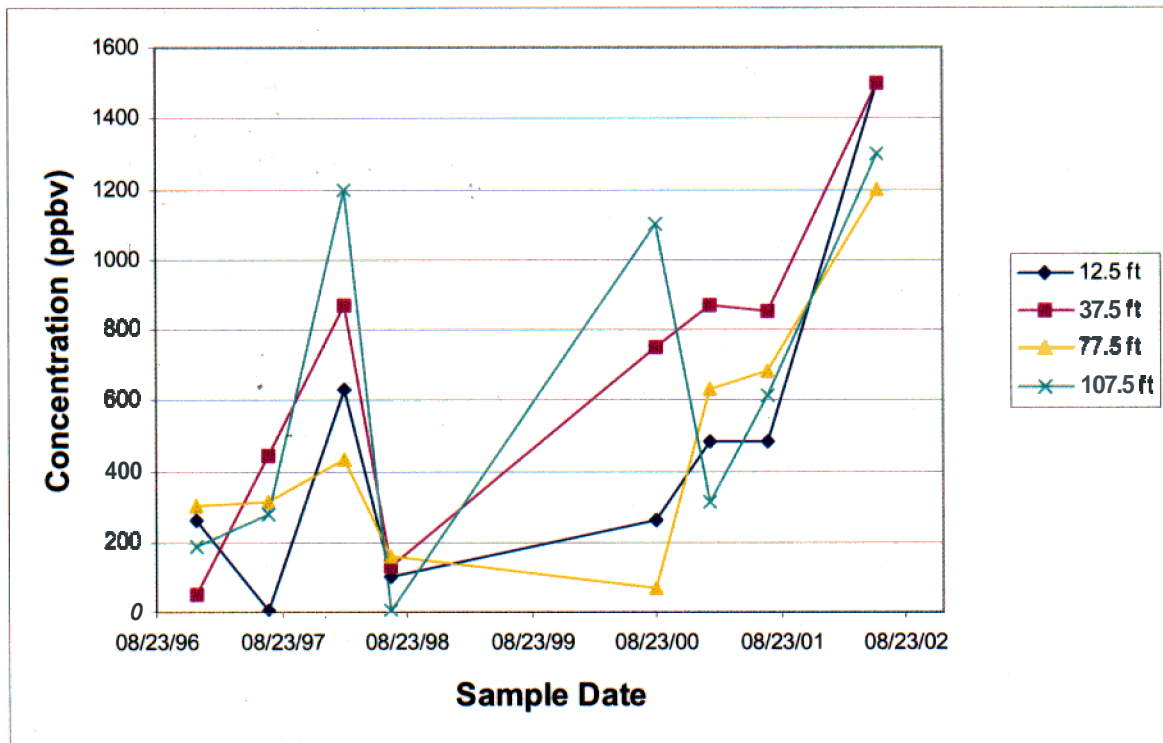


Figure 8d. Dichlorodifluoromethane trends at GSP2-2 on Landfill II (CFA-GAS-V-006).

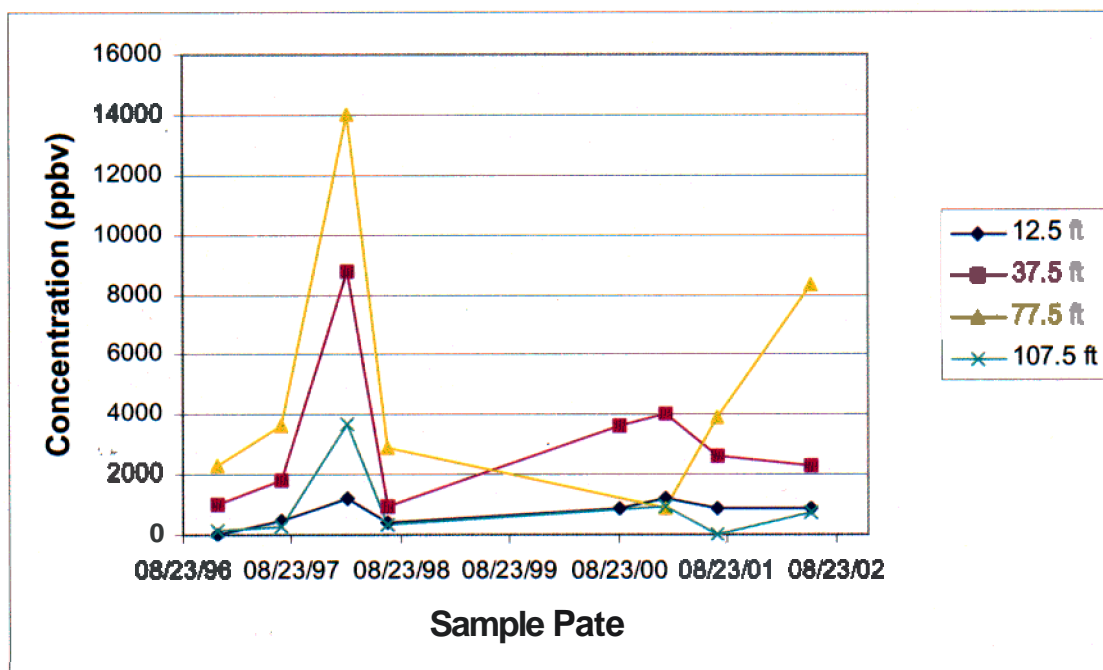


Figure 9a. 1,1,1-trichloroethane trends at GSP3-1 near Landfill III (CFA-GAS-007).

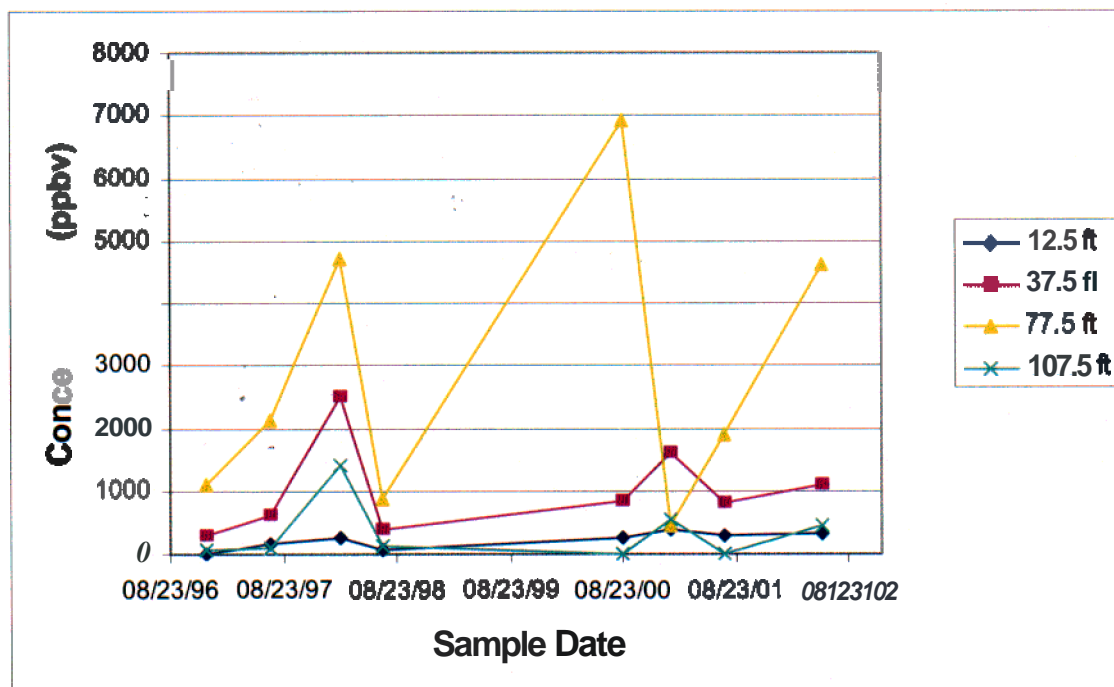


Figure 9b. 1,1-dichloroethene trends at GSP3-1 near Landfill III (CFA-GAS-007).

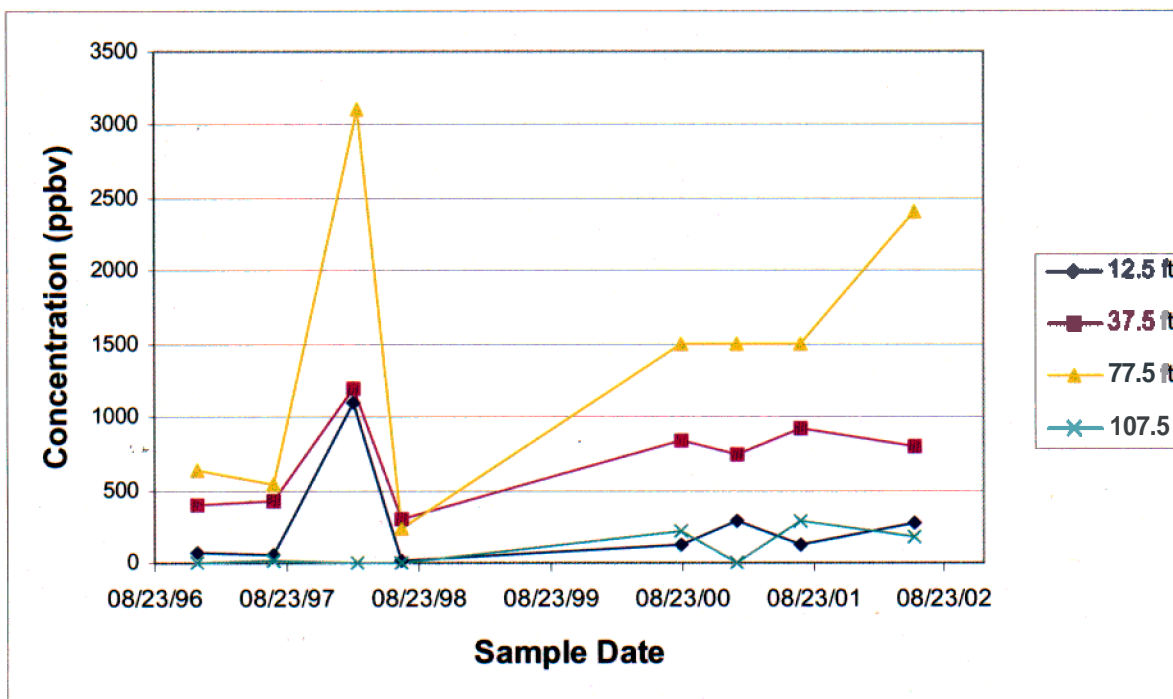


Figure 10a. 1,1,1-trichloroethane concentration trends at GSP3-2 near Landfill III (CFA-GAS-V-008).

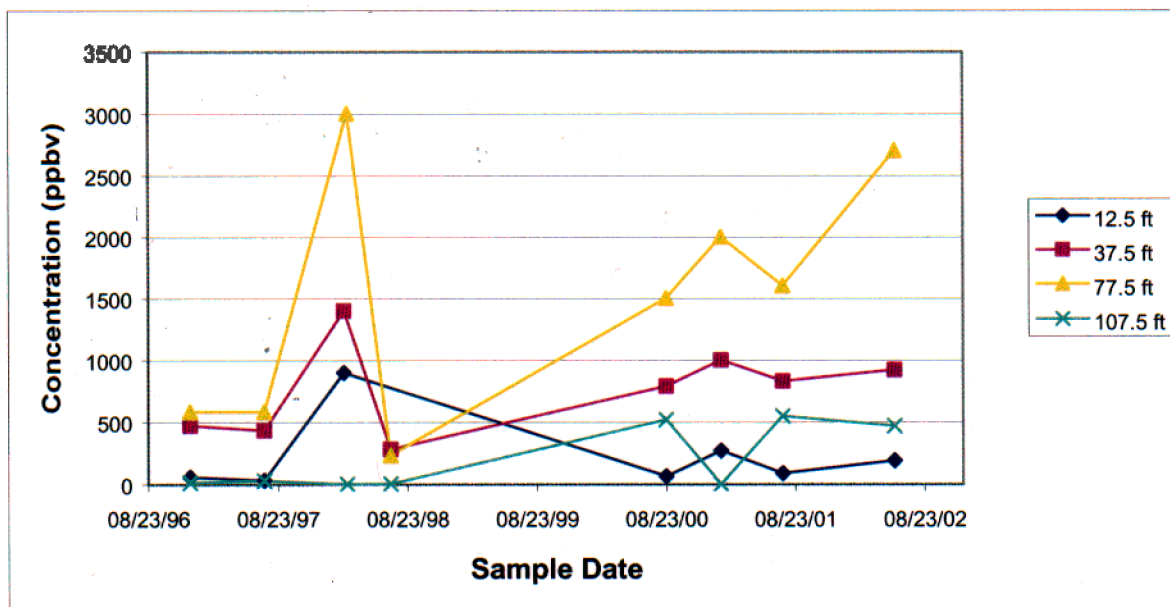


Figure 10b. Trichlorofluoromethane concentration trends at GSP3-2 near Landfill III (CFA-GAS-V-008).

4. MOISTURE MONITORING RESULTS

The overall objective of moisture monitoring at the CFA landfills is to document the effectiveness of the landfill covers for minimizing infiltration into the landfill wastes (INEL 1997a). Infiltration was estimated by using moisture measurements that were determined using neutron probe and TDR instruments. The location of the vertical TDR systems installed in the native soil cover at CFA Landfills II and III to a depth of 8 ft and the five existing NATs are shown in Figure 6. The two TDR arrays located on Landfill II are near NAT LF2-07. NAT LF2-07 is located on Landfill II, and LF2-03 is located on the edge of Landfill II. LF2-04 is located near Landfill II and is used for monitoring infiltration and recharge in native soil or background conditions. NAT LF3-05 is located on Landfill III, and LF3-03 is located on the edge of Landfill III. The raw data and graphs of the moisture content data are presented in Appendix B.

The terms “infiltration, recharge, and drainage” are used throughout this section and are defined as follows. Water that moves into the soil is defined as “infiltration.” Water that continues to move downward beyond the ET depth and out of the soil profile is termed “recharge.” Infiltration and recharge are represented by an increase in water storage within a system. In addition to recharge, ET is a large contributor to decreasing storage in near-surface soils, moving water upward and out of the soil. The term “drainage” refers to water movement out of a unit thickness of soil or a decrease in soil moisture content but does not indicate the direction of movement. A detailed description of the calculations used to estimate infiltration, recharge, and drainage are provided in Appendix B.

4.1 Neutron-Probe Moisture Monitoring Results

The only measurable infiltration event that penetrates beyond the first foot occurred in March and April 2002. Consequently, infiltration and recharge were estimated for this spring event. Those estimates also reflect recharge for the entire year. Based on the change in moisture content using the calibration equations and the assumed ET depth, the estimates of recharge for 2002 range from less than 0.25 to 2.97 in. at LF2-07 (see Table 7). The recharge at LF2-04, the background location near CFA Landfill II, was calculated to be 1.07 in. For spring 2002, infiltration calculations for the five NATs ranged from 1.34 to 5.23 in. The highest amount of infiltration occurred at LF2-07 located at Landfill II near a shallow depression. The shallow depression near LF2-07 is not common on Landfill II and is not representative for most of Landfill II. The TDR locations that are discussed below are more representative of typical conditions on Landfill II. Also, LF3-03 indicated that 1.24 in. of recharge occurred; however, this probe is located on the edge of the landfill and could be influenced by the accumulation of snowdrifts there. The amount of recharge at LF3-03 is similar to the background location LF2-04. LF2-03, located near the edge of CFA Landfill II, had calculated infiltration and recharge less than the background site LF2-04.

Changes in storage refer to changes in soil moisture content over a period that represents a full moisture cycle (typically one year). Changes in storage at the NAT locations for the period of October 2001 to October 2002 indicate the moisture content over the soil profile monitored by the NATs at all locations, except LF3-05, increased in moisture content (see Table 7). However, the change in water storage indicates that moisture contents are generally holding steady within the landfill caps and within the ET zones. Location LF2-07 showed the largest increase in water storage, with 1.10 in. over the entire soil column and 1.05 in. below the ET zone. In contrast, LF2-03 located near the edge of Landfill II, showed almost no change in storage over the entire soil column, within and below the ET zone (see Table 8). The NATs, LF2-04, and LF3-03 showed small positive changes in storage over the entire soil column and below the ET zone.

Table 7. Summary of landfill cover NAT and TDR monitoring results.

	NAT Locations					TDR Locations			
	LF2-03	LF2-04	LF2-07	LF3-03	LF3-05	LF3-east	LF3-west	LF2-north	LF2-south
<i>Spring 2002 infiltration event (in. of water)</i>									
Infiltration	2.11	2.46	5.23	3.77	1.34	5.35	4.72	4.32	0.81
Recharge ^a	0.29	1.07	2.97	1.24	<0.25	<0.25	<0.25	<0.25	<0.25
<i>Oct. 2001 to Oct. 2002 yearly drainage (in. of water)</i>									
Total drainage	4.92	3.85	6.69	4.61	4.34				
Drainage within ET zone ^b						4.85	5.28	4.43	1.08
<i>Change in storage from Oct. 2001 to Oct. 2002 (in. of water)</i>									
Total	0.17	0.49	1.10	0.51	-0.42	0.87	-0.13	-0.03	-0.23
Within cap	—	—	-0.18	0.07	-0.14	-0.17	-0.04	-0.08	-0.22
Within ET zone	0.02	-0.05	0.05	0.10	-0.18	1.1	-0.09	0.00	-0.27
Below ET zone	0.15	0.54	1.05	0.41	-0.24	-0.23	-0.04	-0.03	0.04

a. The amount of recharge is estimated to be the increase in moisture content below ET depth.

b. The ET depth is assumed to be 3 to 4 ft for the NATs and 4 ft for the TDRs.

Table 8. Comparison of pre- and post-cover recharge rates in inches of water at NAT locations

	LF2-04 Background	LF2-03 Edge of LF II	LF2-07 On LF II	LF3-03 Edge of LF III	LF3-05 On LF III	Winter Precipitation
<i>Before New Cover</i>						
1988	5.39	3.24	5.85	1.71	2.07	1.88
1989	10.18	2.55	14.69	2.24	0.87	3.35
1990	4.94	5.39	9.5	1.61	2.08	1.88
1993	3.91	1.11	3.24	3.24	5.17	4.79
<i>After New Cover</i>						
1998	2.25	2.23	2.27	1.84	<0.25	3.43
2001	0.30	<0.25	<0.25	<0.25	<0.25	1.8
2002	1.07	0.29	2.97	1.24	<0.25	2.23

4.2 TDR Monitoring Results

Infiltration, change in storage, and drainage calculations were made for 2002. The primary infiltration and recharge event was the spring snowmelt. The infiltration and drainage results indicate that at three of the four TDR locations, the amount of infiltration is greater than the measured precipitation at the CFA National Oceanic and Atmospheric Administration (NOAA) weather station. The calculated infiltration for the TDR locations ranges from 0.81 to 5.35 in. (see Table 7). However, the measured precipitation at the CFA NOAA weather station is only 2.23 in. Similarly, drainage or losses in storage for the three TDR arrays ranges from 2.25 to 3.84 in. of water. An explanation for the discrepancy between the measured precipitation at the CFA NOAA weather station and the amount of infiltration could be the ponding of water or snowdrifts above the TDR locations. However, neither ponding nor snowdrifts were observed at the locations during snowmelt. The high TDR readings could be related to probe calibration or to physical nonconformities in the subsurface.

Moisture contents generally remained steady below the estimated ET depth of 4 ft (see Table 7); therefore, no or little (i.e., less than 0.25 in.) recharge was indicated at the four TDR locations. The 3.5- to 4-ft interval at LF3-east showed an anomalous rise in soil moisture content starting in July, but this significant increase in moisture content did not show up in the 4- to 4.5-ft interval, and only a modest rise occurred in the 3- to 3.5-ft interval. No intervals below 4 ft showed a significant increase in moisture content, suggesting that any recharge was slight and ET consumed most to all of the infiltrated water for the spring 2002 snowmelt.

In contrast to the spring snowmelt (March and April 2002), three precipitation events in 2002 appeared to affect only the 0- to 6-in. depth interval. Precipitation in the form of rain fell on May 21, June 22, and September 6 and 7. These precipitation events are reflected at the 6-in. depth, but there appears to be little response below this depth. The estimated amount of infiltration into the 0- to 6-in. depth is about one-half the amount of precipitation for all three events.

An evaluation of the water storage showed that little change occurred at the four TDR locations over the year. At CFA Landfills II and III, from depths of 4 to 8 ft or below the estimated ET depth of 4 ft, there was essentially no change in storage. There was little change in storage over the monitoring period for the 0- to 2-ft depth intervals for the landfill caps at the four TDR locations (see Table 7). Three

of the four TDR locations showed a loss in storage for the 0- to 8-ft depth interval over the monitoring period (see Table 7). Changes in storage at CFA Landfill II were -0.03 and -0.23 in. At CFA Landfill III, changes in storage were 0.87 and -0.13 in.

4.3 Comparison of TDR and Neutron Probe Data

The TDR and the neutron probe data from LF3-05 in CFA Landfill III indicated there was no recharge below 4 ft. However, the amount of infiltration estimated using the TDR data was considerably higher than infiltration for LF3-05. The discrepancy between the estimated infiltration values for the two TDRs and the neutron probe at LF3-05 could be because the TDR probes have not been calibrated. The TDRs need to be calibrated to verify the accuracy of the moisture data.

In CFA Landfill II, the two TDRs and LF2-07 showed dramatically different results. The TDRs did not show any recharge, whereas LF2-07 showed almost 3 in. of recharge. The higher recharge at LF2-07 could be due to accumulation of snow and runoff in a low spot located around LF2-07.

4.4 Comparison of Moisture Data Collected Before and After Installation of New Cover

Vadose zone moisture monitoring was conducted at CFA Landfills II and III from 1988 to 1990 and in 1993 at the five NAT locations (INEL 1995). Calculations based on changes in total soil profile moisture indicate that significant deep drainage (recharge) occurred. The amount of recharge ranged from 1.71 to 5.85 in. in 1988, 0.87 to 14.69 in. in 1989, 1.61 to 9.5 in. in 1990, and 1.11 to 5.17 in. in 1993. The highest amount of recharge occurred at LF2-07, except in 1993 when the highest amount occurred at LF3-05. The estimates for deep drainage are given in Table 8.

Comparing the data for LF3-05 before and after the installation of the new cover shows that deep drainage or recharge was significantly reduced (see Table 8). Before the cover, deep drainage at LF3-05 ranged from 0.87 to 5.17 in., but after the new cover was constructed, the recharge was below 0.25 in. Recharge has been reduced significantly at LF3-05 by the installation of the new cover.

At CFA Landfill II, the deep drainage calculations for LF2-07 ranged from 3.24 to 14.69 in. before the new landfill cover. The recharge calculations after emplacement of the cover range from less than 0.25 to 2.97 in. The decreases in recharge after the installation of the new cover are significant at LF2-07 and not as significant for LF3-05.

5. NITRATE SOURCE RE-EVALUATION

The source of elevated nitrate in CFA-MON-A-002 and -003 was previously determined to be the CFA-08 sewage treatment plant drainfield (INEEL 2002). The source of the nitrate is being re-evaluated for the following reasons:

- The GWSCREEN model predications (INEEL 2002) indicated that the nitrate concentrations should be decreasing by now in the CFA-MON wells. The previous GWSCREEN model in INEEL (2002) has been redone using HYDRUS 2-D, because this model better accounts for transient conditions that would occur after flow to the drainfield ceased.
- A water-level map was constructed using new borehole deviation survey data for 15 wells completed in November 2002. The new water-level contour map is reviewed with respect to potential nitrate sources.
- A new potential source of nitrate was identified as the land farm area for petroleum-contaminated soil, because manure and water were applied to the CFA Land Farm to promote biodegradation.

The purpose of this section is to review the new water-level map, groundwater chemistry, and new hydrus 2-D modeling to determine if the previous conclusion that the CFA-08 drainfield is the source of the nitrate observed in the CFA-MON wells is still valid. This analysis also includes a re-examination of the assumptions on the groundwater flow direction in the original GWSCREEN modeling. The sites reviewed as potential nitrate sources are the CFA Land Farm, CFA-04, and CFA-08.

5.1 Evaluation of the CFA Land Farm as a Potential Nitrate Source

A potential nitrate source is the 27-acre land farm located north of the CFA monitoring wells. Operation of the land farm began in 1994 with the purpose of providing a medium for biodegradation of petroleum-contaminated soils. To enhance biodegradation, manure from nearby dairy farm operations was imported. The manure was spread over the land farm to a depth of about 6 in. and later tilled into the contaminated soil. The land farm was occasionally sprayed with water during the summer months for dust suppression. The manure was only applied during the first couple years of operation. The manure contains reduced forms of nitrogen, such as ammonia and nitrate.

The nitrate in the manure is a potential, but unlikely, source of the nitrate observed in the CFA monitoring wells. It is eliminated as a source of nitrate, because the transit time of infiltration from the land farm to the aquifer and transport in groundwater to the monitoring wells was too long for it to have arrived within two years. Under the fastest infiltration conditions, it is estimated that nitrate originating in the land farm would take 30 years to reach the aquifer (not considering horizontal flow in the aquifer); therefore, it could not be the cause of elevated nitrate found in the CFA-MON wells in 1996, when these wells were first sampled. The vadose zone travel time estimate assumes an average 4 in. of water infiltrates per year, a moisture content of 0.3, 33 ft of sedimentary interbeds, and instantaneous transport through the basalt with these estimates coming from the Track 2 guidance (DOE-ID 1994b). The additional water sprayed on the land farm during the summer months for dust suppression is not sufficient to increase water transit times. Much of this water would be lost to ET during the summer. Therefore, the CFA land farm has been eliminated as a plausible source for the nitrate observed in CFA-MON-A-002 and -003 wells.

5.2 Evaluation of CFA-04 and CFA-08 as Nitrate Sources

Based on current information, the two most likely sources of nitrate found in the CFA-MON wells are CFA-04 (dry pond) and CFA-08 (drainfield). The wastes deposited into the CFA-04 dry pond came from Building CFA-674, which contained the Chemical Engineering Laboratory (CEL). The types of wastes deposited in the CFA-04 dry pond included mercury-contaminated wastes from calcine development work (1953 – 1965), liquid laboratory effluent from the CEL (1953 – 1969), and bulky waste that included asbestos-containing roofing material from construction projects at the INEEL. The types of waste from the CEL may have included simulated calcine, sodium, nitrate, nitric acid, uranyl nitrate, high-grade kerosene, aluminum nitrate, hydrochloric acid, di-chromate solutions, terphenyls, heating oil, zirconium, hydrofluoric acid, trichloroethene, and acetone (DOE-ID 2000). Although the CFA-04 dry pond has not received laboratory wastes since 1969, the nitrates in CFA-MON-A-002 and -003 could be from CFA-04 because of the time lag between disposal to the pond and migration into the aquifer. The travel time for nitrate to the aquifer from CFA-04 was estimated to be 39 years using GWSCREEN (INEEL 1999). Groundwater level data, nitrate plume chemistry, and HYDRUS modeling of CFA-08 were evaluated to determine the source of nitrate in CFA-MON-A-002 and -003.

5.2.1 Groundwater Flow Direction

Previously, when the source of nitrate in the CFA-MON wells was evaluated, groundwater was thought to flow southwest from the CFA-08 drainfield (INEEL 2002). This flow direction also influenced the interpretation of the nitrogen isotope data. The current groundwater-level map, constructed from new borehole deviation corrections, shows the CFA-08 drainfield is not upgradient of the CFA-MON wells (see Figure 3). The groundwater-level map constructed using the new borehole deviation corrections is similar to recent water-level maps (DOE-ID 2002). The groundwater-level map drawn from the data collected in 2002 shows that CFA-04 is directly upgradient of CFA-MON-A-002 and -003. Therefore, the new groundwater flow direction indicates the source of the nitrate contamination is the CFA-04 dry pond.

5.2.2 Nitrate Plume Chemistry

The nitrate plume chemistry was examined to characterize or fingerprint the source of the nitrate. The chemical signature of water in the monitoring wells shows elevated concentrations of calcium, chloride, magnesium, potassium, and probably sodium relative to background for the SRPA and other wells in the immediate vicinity (i.e., USGS-083 and CFA-MON-A-001). Both nitrate and these constituents are higher in CFA-MON-A-002 than in CFA-MON-A-003. CFA-04 and the CFA-08 drainfield could produce water with these geochemical signatures, because the release sites involve neutralization reactions. The oxidation of reduced ammonia would increase nitrate, calcium, and magnesium concentrations. Reduced N^{-3} species are represented by the total Kjeldahl nitrogen (TKN) number and are predominantly ammonia. The oxidation of ammonia can be written as:



The generation of excess H^+ by the oxidation of reduced nitrogen is neutralized by interaction with calcite or dolomite. Similarly, acidic wastes disposed of in the CFA-04 dry pond would also be neutralized by reaction with carbonate minerals. The neutralization reaction with calcite can be expressed as:



The above reactions should lead to a nearly one-for-one molar increase in nitrate and calcium concentrations. Interaction with dolomite or high-magnesium calcite would also elevate magnesium

concentrations. Reactions with calcium/magnesium carbonates in the underlying sediments or in fractures in the basalt could shift the magnesium/calcium ratio if most of the nitrogen in the CFA-08 drainfield is in a reduced state. However, the effluent to the CFA-08 drainfield contains a relatively low amount of TKN in comparison to the TKN content of the INTEC effluent (see Table 9). The small amount of TKN in CFA-08 effluent suggests the calcium and magnesium concentrations would not be changed significantly. Thus, water leaching from the drainfield should show the characteristics of the effluent and upgradient water.

Although both potential sources could cause the same constituents to be elevated, the ratios of plume components could vary. Various ratios are examined below to characterize the nitrate source. In addition, the CFA-08 drainfield overlies groundwater containing the INTEC chloride and sodium plume, and the contribution to the ratios from the INTEC plume must be considered.

Although the TKN content does not appear high enough to significantly impact cation ratios, the high sodium concentrations in the CFA-08 effluent could modify the concentrations of calcium and magnesium through ion exchange. Similarly, if high sodium wastes were deposited into the CFA-04 dry pond, then ion exchange could affect the concentrations and ratios of calcium and magnesium from this site as well, even if acidic wastes are neutralized prior to disposal.

In addition to the inorganics listed above, on occasion, trimethyl benzenes and methane have been detected in CFA-MON-A-002. The trimethyl benzenes are associated with fuels, and methane is typically a breakdown product of organic material, including fuels. The occurrence of tritium in CFA-MON-A-002 and -003 may be associated with the nitrate plume and not just part of the local tritium plume. The highest tritium concentration is associated with the well with the highest concentrations of nitrate and other plume parameters.

5.2.2.1 Major Ion Data. The major ion chemistry was examined to verify the groundwater flow paths. It may be possible to deduce or isolate various water types in the aquifer by comparing the constituents in the nitrate plume (CFA-MON-A-002 and -003) to concentrations and ratios for the CFA landfill wells, the CFA production wells, the INTEC water supply, MW-24 (perched water well near the INTEC sewage infiltration ponds), and effluent to the CFA-08 drainfield. The composition of water sources and CFA-08 effluent are given in Table 9. The composition of MW-24, a perched water well located near the INTEC sewage treatment facility, is also shown for comparison.

A Piper diagram was constructed to examine the major cation and anion characteristics of wells in the CFA vicinity (see Figure 11). The Piper diagram in Figure 11 shows the relative composition of USGS-083 and CFA-MON-A-001 are nearly the same as the INTEC water supply. CFA-MON-A-002 and -003 are shifted away from the CFA landfill wells by higher magnesium concentrations. The data in Table 9 show the magnesium concentrations are higher in CFA-MON-A-002 and -003 than in the CFA landfill wells. The anion portion of the Piper diagram indicates that sulfate concentrations are similar in all of the wells. Plot variation is due primarily to differences in chloride concentration.

The groundwater level map (see Figure 3) indicates that CFA-MON-A-001 and USGS-083 are on the same flow path and both wells have similar ratios of magnesium/calcium and chloride/hydrate (see Figure 12). Although CFA-MON-A-001 and USGS-083 are not affected by nitrate contamination, both wells have magnesium/calcium versus chloride/hydrate ratios similar to CFA-MON-A-002 and -003, suggesting these wells tap similar groundwater. The magnesium/calcium ratio versus chloride/hydrate ratio shows the CFA-MON wells, including USGS-083, plot in distinctly different areas than the CFA landfill wells (see Figure 12). The CFA production wells plot between the CFA-MON wells and the landfill wells

Table 9. Common ion characteristics of water sources and CFA-08 possible nitrate source.

Source	Date	Sample	Sodium mg/L	Potassium mg/L	Magnesium mg/L	Chloride mg/L	Sulfate mg/L	Nitrate mg/L - N	Calcium mg/L	TKN ^a mg/L - N
CFA Production Wells	6/8/1993	CFA-1 ^b	29.3	4.29	20	96.3	33.4	4.58	64.5	
	10/26/1993	CFA-2 ^c	18.4	3.25	21.8	85.2	37.2	3.1	62.9	
Effluent to CFA-08	5/31/1994	CFA-674 effluent ^d	55.2	5.86	22.4	144	42.6	4.8	65.5	1.4
	Average ^e		81.8	6.148	21.543	222	52.4	3.18	63.506	2.18
INTEC Water Supply ^f	4/95-6/95	CPP-01	9.11	2.98	17	18	24	1.1	58.1	
INTEC Sewage Treatment	Average ^g	Sewage effluent	66.3	12.4	15.4	111	36.6	1.44	45.9	15.6
	3/7/2001	MW-24	61.3	9.43	18.9	79.3	33.8	12.2	82.5	
Monitoring Wells										
		LF2-08	41.8	4.54	17.9	113	31.8	3.37	66.5	
		LF2-09	43	5.04	18.8	103	28.9	3.27	75.9	
		LF2-11	44.9	4.36	17	107	29.6	3.3	60.4	
		LF3-08	37.5	4.51	17.1	99.5	27.8	3.12	60.3	
		LF3-09	37.6	4.42	20.6	114	29.1	3.47	70.4	
		LF3-10	35.7	3.81	15.9	79.7	27.1	2.8	60.4	
		USGS-128	21.9	2.99	14.3	36.9	28.2	1.77	55.5	
		LF3-10 (Dup)	34.9	3.76	15.5	80.1	27.1	2.74	60.2	
		CFA-MON-A-001	9.68	2.62	13.6	21.6	18.8	1.62	34.8	
		CFA-MON-A-002	16	4.27	25.4	54.4	26.6	19.8	61.3	
		CFA-MON-A-003	12.2	3.31	21.9	43.2	23.1	11	48.5	
		USGS-083	10.3	2.46	11.4	10.2	19.7	0.71	29.1	

a. TKN includes total nitrogen in the N⁻³ state.

b. Recent data from 2000 and 2001 for chloride (108 mg/L), sodium (27.9 mg/L), and sulfate (30.88 mg/L) from CFA-1 are similar in concentration to this analysis.

c. Recent data from 2000 and 2001 indicate that sulfate (47 mg/L), sodium (29 mg/L), chloride (122 mg/L), and nitrate (4.1 mg/L) concentrations are slightly higher.

d. Sample of effluent with low chloride, high nitrate, and low TKN.

e. Average values from 1988 to 1994.

f. Before chlorination of the potable water.

g. Average values from January 1997 to July 2002.

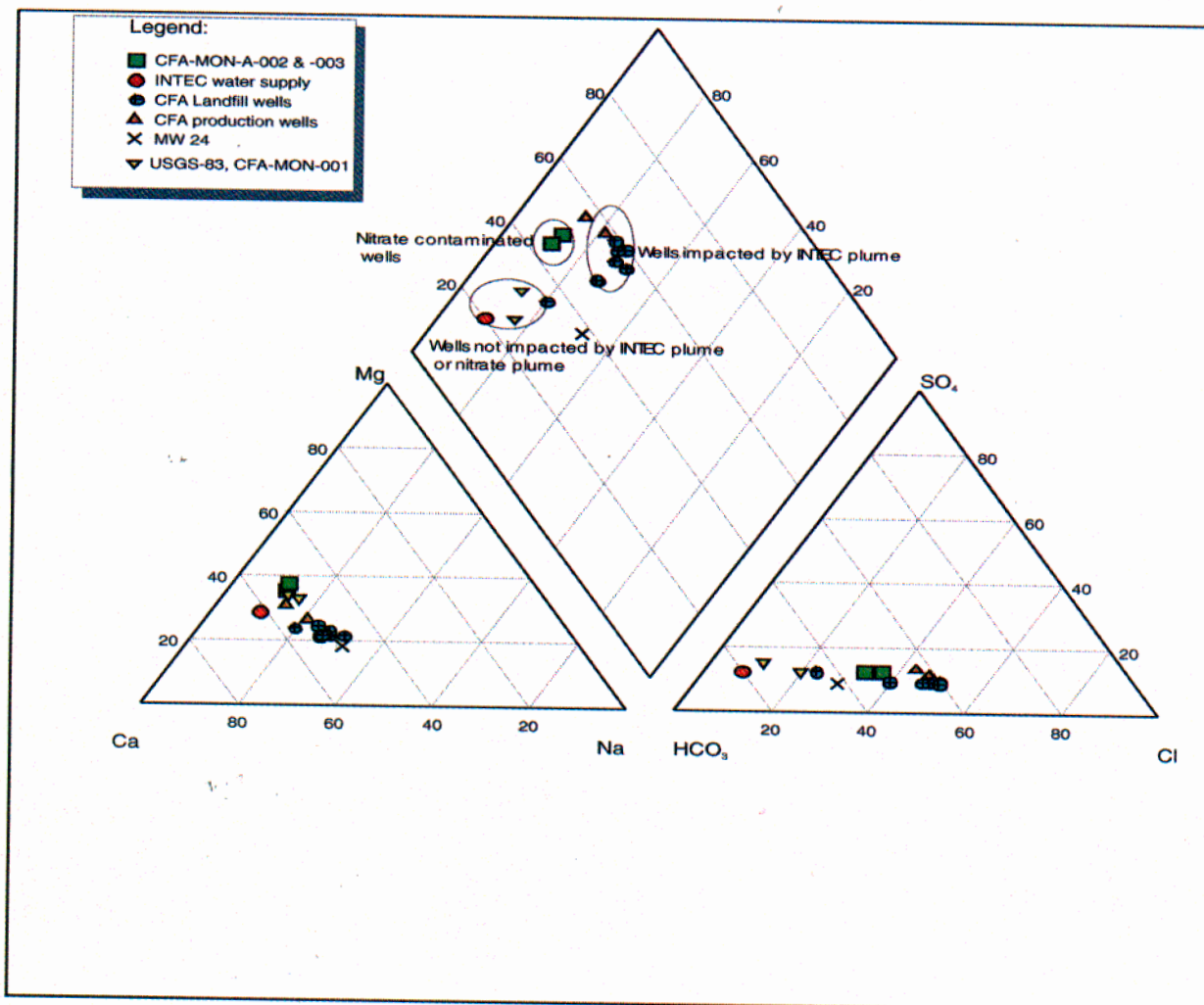


Figure 11. Piper diagram.

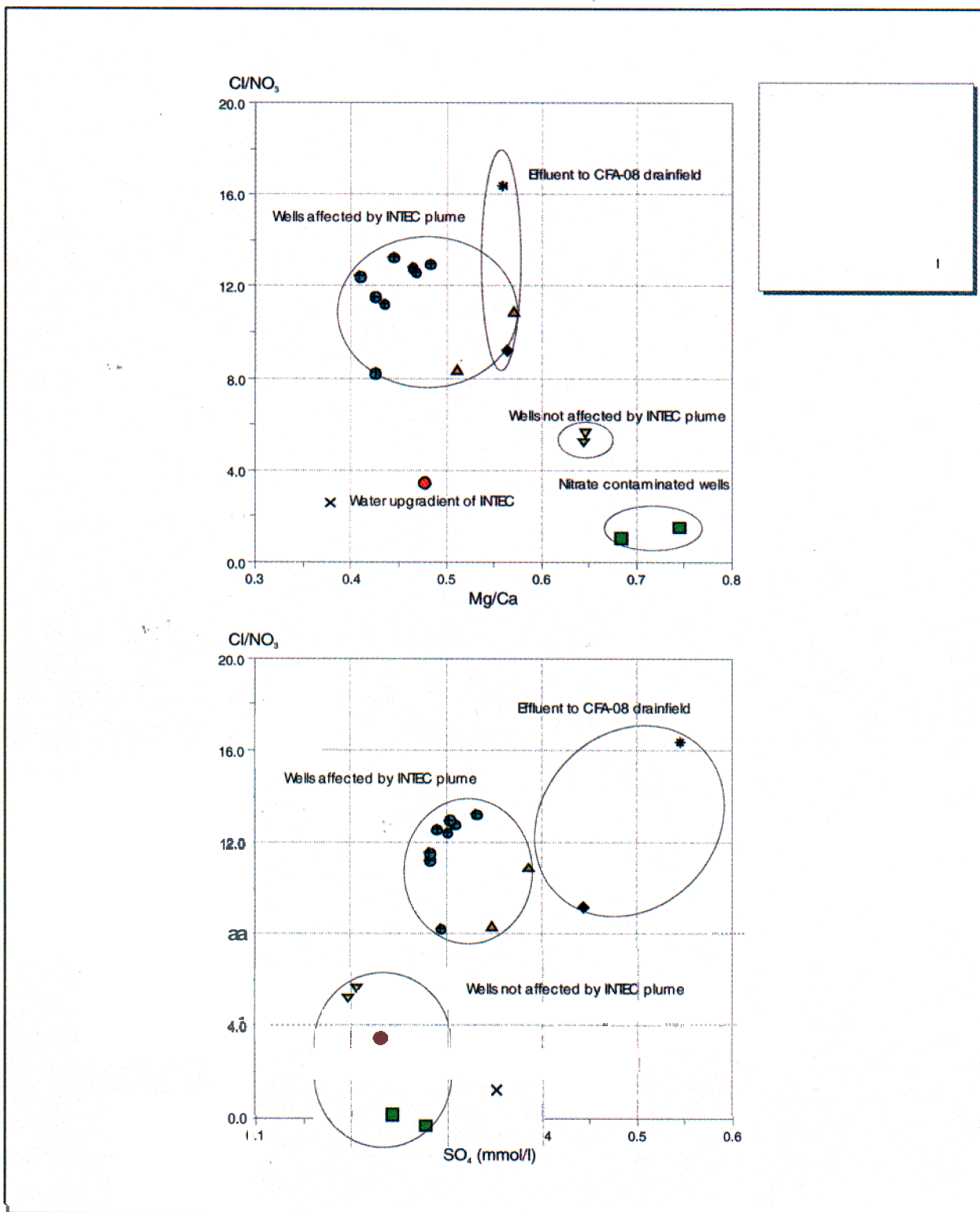


Figure 12. Plots of anion and cation ratios (the nitrate concentrations for the CFA-08 effluent samples have been adjusted to assume that all the TKN is converted to nitrate).

but closer to the landfill wells. This is consistent with the wells being on a different flow path, as indicated by the groundwater-level map. The magnesium/calcium ratio in the CFA-MON wells indicates that the CFA-08 drainfield is not the source of nitrate.

Because the INTEC plume contains high levels of sodium relative to the background concentrations in the SRPA, ion exchange could affect the calcium/magnesium ratio. However, the water upgradient of INTEC has a calcium/magnesium ratio similar to the CFA landfill wells downgradient of the INTEC plume. Although ion exchange is increasing calcium and magnesium concentrations in the downgradient CFA landfill wells, the calcium/magnesium ratio is relatively unaffected.

The chloride/nitrate versus sulfate plot shows the three CFA-MON wells and USGS-083 plot in the vicinity of the water supply for INTEC and suggests the CFA-MON wells are not affected by the INTEC plume (see Figure 12). This supports the premise that the CFA-MON wells are not on a direct flow path from CFA-08 as indicated by water-level data. The CFA production wells appear to be near the CFA landfill wells and suggest the INTEC plume affects the production wells. That the CFA production wells are affected by the INTEC plume is directly indicated by the high chloride and tritium concentrations in the wells and the occurrence of 1-129 in CFA-1 (DOE-ID 2002a).

If chloride and nitrate both act as conservative tracers and the CFA-MON wells are on a direct groundwater flow path from the CFA-08 drainfield, then the chloride concentration in the aquifer should increase substantially above the 80 to 100 mg/L background range for the CFA-08 drainfield in concert with increasing nitrate concentrations. The CFA-08 drainfield is located within the INTEC chloride plume, so the background concentrations are probably around 80 to 100 mg/L, given that chloride generally is between 80 and 100 mg/L in CFA-1 located near the CFA-08 drainfield. The available effluent data to the CFA-08 drainfield indicate that the nitrate concentrations are too low—on order of 6 to 10 mg/L of total nitrogen—to account for the contamination in the CFA-MON wells (10 to 20 mg/L-N). In addition, chloride concentrations are too low in CFA-MON-A-002 (54.4 mg/L) and -003 (43.2 mg/L) to be on a direct flow path from CFA-08 drainfield, given the average concentration of chloride in the effluent (222 mg/L) to the drainfield and the background concentration of the aquifer at CFA-08 (80 to 100 mg/L) for the CFA-MON wells. In addition, the chloride/nitrate ratios in the CFA-MON wells are not consistent with the effluent to the drainfield. Ratios of chloride to nitrate in CFA-MON-A-002 and -003 wells are 3:1 and 4:1, but the chloride versus nitrate in the effluent to the drainfield is more than 10:1. Given that the background chloride/nitrate ratio is close to 30:1 in the INTEC chloride plume, the chloride/nitrate ratios suggest that the CFA-08 drainfield is not the source of the nitrate contamination in the CFA-MON wells. The concentrations and ratios of chloride and nitrate both suggest that the CFA-MON wells are not on a direct groundwater flow path from the CFA-08 drainfield.

5.2.2.2 Stable Isotope Data. The CFA-08 drainfield was implicated as the source of the nitrate contamination based on the nitrogen isotope study done in 2000 and the assumption that groundwater flow was to the southwest (INEEL 2002). The nitrogen isotope study showed that the CFA-MON wells and CFA-1 (USGS 1999) had higher $\delta^{15}\text{N}$ values than the CFA landfill wells. Because the $\delta^{15}\text{N}$ values for the CFA-MON wells were higher than background and close to levels found downgradient of sewage treatment plants, it seemed likely that the CFA-08 drainfield was the source of the nitrate, even though the recorded total nitrogen contents of discharge to the drainfield from 1988 to 1995 are too low to cause the nitrate concentrations in CFA-MON-A-002. The CFA-04 dry pond was ruled out as a source of the nitrate, because the $\delta^{15}\text{N}$ of commercially produced nitrate should be 0 ± 4 per mil, because the nitrogen used in commercial processes is drawn from the atmosphere.

One possibility that was not examined using the nitrogen isotope data is that the isotopic signature of the nitrate discharged into the CFA-04 dry pond could have been altered by a loss of nitrate to the

atmosphere. Disposal of liquid nitrate-bearing waste disposed to the dry pond would have the effect of increasing the $\delta^{15}\text{N}$ value. However, a quantitative analysis cannot be performed, because a fractionation value is not available to calculate nitrate loss required to reach values of 7 to 8 per mil $\delta^{15}\text{N}$ (observed in the CFA-MON wells) from a starting value of 0 ± 4 per mil. Because isotopic fractionation of the liquid nitrate-bearing wastes could have occurred, the use of only $\delta^{15}\text{N}$ data may not be sufficient (or appropriate) to distinguish sources of nitrate.

The $\delta^{18}\text{O}$ of nitrate can be used in combination with $\delta^{15}\text{N}$ data to determine the source of the nitrate. Nitrate used in acids would derive oxygen from the atmosphere with a $\delta^{18}\text{O}$ of 23.5 per mil (Amberger and Schmidt 1987). The nitrate formed from the oxidation of reduced nitrogen species in sewage derives two of its oxygen atoms from the local water and one from air (Clark and Fritz 1997). The local precipitation is -17 to -18 per mil $\delta^{18}\text{O}$ (USGS 1999, DOE-ID 2002). Consequently, sampling the three CFA-MON wells, CFA-1, CFA-2, LF3-08, and LF2-11 for $\delta^{15}\text{N}$ nitrate and $\delta^{18}\text{O}$ nitrate could help resolve the nitrate source issue.

In addition, the occurrence of methane in CFA-MON-A-001 and -002 could indicate that reducing conditions are present in the vadose zone or at some point along the migration pathway of the nitrate plume. The reducing conditions could lead to denitrification. The process of denitrification can also increase the $\delta^{15}\text{N}$ of nitrate. The use of $\delta^{18}\text{O}$ of nitrate could also be used to resolve this issue.

5.2.2.3 Other Nitrate Plume Constituents. Other plume constituents were examined to determine if their occurrence could further define or eliminate potential sources.

The tritium associated with the nitrate plume could be from water pumped from the CFA production wells or from the upgradient INTEC plume. The water discharged to the CFA-08 drainfield is from the CFA production wells and would contain tritium. Liquid wastes discharged from the CFA-674, CEL to the CFA-04 dry pond could also contain tritium, because the building used the CFA water supply. The presence of tritium cannot be used to distinguish the source responsible for the nitrate contamination.

The occurrence of trimethyl benzenes and methane in CFA-MON-A-002 cannot be used to distinguish the source of the nitrate. The occurrence of trimethyl benzenes in CFA-MON-A-002 and -003 wells could be related to the disposal of kerosene in the CFA-04 dry pond (DOE-ID 2000). Alternatively, the older maps of CFA show that CFA-664 (bus wash) and CFA-665 (old Big Shop) had their floor drains tied to the CFA sewage treatment plant and drainfield. The occurrence of methane in CFA-MON-A-002 and -001 could be due to either the CFA-08 drainfield or degradation of kerosene disposed of in the CFA-04 dry pond.

5.2.3 Hydrus-2D and GWSCREEN Modeling of CFA-08

An update of the initial simulation for the nitrate migration from the CFA-08 drainfield was performed, incorporating new models, data, and other pertinent information. The analysis is summarized here, and the details of the analysis are presented in Appendix C. The modeling analysis suggests it is possible for the CFA-08 drainfield to be the source of the nitrate observed in the CFA monitoring wells if the groundwater flow is $\text{S } 18^\circ\text{W}$, the Darcy velocity is 12.5 m/yr , and the source had a concentration of 25 mg/L . Both chloride and nitrate were present at elevated concentrations in the drainfield effluent. The model predicted that both would be present in the CFA-MON wells at the same relative concentration. However, the chloride:nitrate ratios in the CFA-08 effluent do not match the chloride:nitrate ratios in CFA-MON-A-002 and -003 wells. Additionally, recent water head elevation maps indicate a mean direction of groundwater flow trending southeast instead of $\text{S } 18^\circ\text{W}$, which was the direction assumed for

the original nitrate source assessment. Taken together, the evidence suggests the CFA-08 drainfield is not the source of nitrate observed in the CFA monitoring wells.

5.2.4 Nitrate Source Conclusions

The evidence suggests that the CFA-08 drainfield is not the source of nitrate in CFA-MON-A-002 and -003. The CFA-04 dry pond is the most likely source of nitrate unless another source of nitrate can be identified in the southern part of CFA. The lines of evidence include the following:

- The water-level map drawn from the data collected in 2002 shows that the CFA-04 dry pond is the source of the nitrate contamination, because the CFA-04 dry pond is directly upgradient of CFA MON-A-002 and CFA-MON-A-003.
- The concentrations of total nitrogen in the effluent (5.4 mg/L-N average) to the CFA-08 drainfield are too low to cause the nitrate concentrations in CFA-MON-A-002 (16 to 20 mg/L-N). The new hydrus-2D/GWSCREEN modeling analysis suggests that the source needs a concentration of at least 25 mg/L.
- The major ion chemistry evaluation supports the premise that the CFA-MON wells are not on a direct flow path from the CFA-08 drainfield or the CFA landfills.
- The nitrogen isotope data suggests that the CFA-08 drainfield is the source. However, the $\delta^{18}\text{O}$ of nitrate is needed in combination with $\delta^{15}\text{N}$ data to definitively determine the source of the nitrate.

6. SUMMARY

The only constituent exceeding a groundwater MCL is nitrate. Over time, plots of nitrate concentrations in CFA-MON-A-002 and -003 show the concentrations are remaining steady. Iron and aluminum were detected above SMCLs, but both appear to be associated with suspended particulates.

The new water-level data, groundwater chemistry data, and modeling results suggest that the CFA-08 drainfield is not responsible for the nitrate contamination in CFA-MON-A-002 and -003. The data suggest that the CFA-04 dry pond is a better candidate as the source of the nitrate contamination. Based on evaluation of the groundwater chemistry, the CFA landfills are not the source of the nitrates. However, more information is needed on the types and quantities of nitrate disposed of in the CFA-04 dry pond.

The most common VOCs detected in the soil gas samples include 1,1,1-trichloroethane, 1,1-dichloroethane, 1,1-dichloroethene, and trichloroethene, all of which are common solvents or constituents found in solvents used for cleaning mechanical equipment. Dichlorodifluoromethane and trichlorofluoromethane are freons used in cooling systems. The VOC that occurred at the highest concentrations was 1,1,1-trichloroethane at 8,600 ppbv. Other solvents detected in the soil gas samples included chloroethane, F-113, F-114, carbon tetrachloride, and tetrachloroethene. Cis-1,2-dichloroethene was also detected and frequently occurs as result of the anaerobic degradation of chlorinated ethenes like trichloroethene and tetrachloroethene. None of these VOCs were detected in the groundwater.

The TDR and neutron probe results for 2002 did not show any recharge in CFA Landfill III, but in CFA Landfill II, the two TDRs and NAT LF2-07 showed dramatically different results. The TDRs on CFA Landfill II did not show any recharge, whereas LF2-07 showed almost 3 in. of recharge. The higher recharge at LF2-07 could be due to a low area around LF2-07 that collected snow and runoff water. LF2-03, located near the edge of CFA Landfill II, had calculated infiltration and recharge less than the background site LF2-04. At LF3-03, 1.24 in. of recharge occurred; however, this probe is located on the edge of the landfill and could be influenced by the accumulation of snowdrifts there. The amount of recharge at LF3-03 is similar to the NAT, LF2-04, located off CFA Landfill II for monitoring infiltration and recharge in native soil or background conditions.

The moisture data for the NATs located on CFA Landfills II and III indicate the cover has reduced infiltration. Comparing the data for NAT LF3-05 before and after the installation of the new cover shows that deep drainage or recharge was significantly reduced by the installation of the new cover. At CFA Landfill II, the decreases in recharge after the installation of the new cover are significant at LF2-07 although not as significant for LF3-05 on Landfill III.

7. RECOMMENDATIONS

The following recommendations are made to clarify the nitrate issue and potential groundwater flow paths from the CFA landfills:

- Two new wells are recommended for the CFA landfills. One monitoring well is recommended south-southeast of Landfill I, and one well is proposed for the southeast corner of Landfill II. Vapor ports will also be installed in these wells near the water table.
- It is recommended that the nitrogen isotope samples be retaken and that the $\delta^{18}\text{O}$ of nitrate also be determined to confirm the source of the nitrate. The wells for the $\delta^{15}\text{N}$ nitrate and $\delta^{18}\text{O}$ nitrate resampling would include the three CFA-MON wells, CFA-1, CFA-2, LF3-08, LF2-08, and LF2-11.
- Infiltration modeling of the landfill covers could be performed to evaluate the long-term performance of the covers. Modeling could be performed to determine if different types of vegetation than what is currently on the landfills would improve the performance of the covers. Modeling could also be performed to determine how much infiltration can be tolerated before significant concentrations of contaminants would be detected in the groundwater.
- A capture zone analysis for the CFA production wells might aid in evaluating the impact of the production wells on water levels and groundwater flow paths. This analysis would be useful for evaluating the potential migration of contaminants from the CFA landfills, the CFA-08 drainfield, and CFA-04.
- Calibration of the TDR arrays may improve infiltration estimates. Calibration soil samples could be taken in the spring (March or April) at four 6-in. intervals for the first two feet near each TDR.

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